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MODERN SCIENCE AND MODERN THOUGHT

BY

SAMUEL LAING

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MODERN SCIENCE

AND MODERN THOUGHT.

WITH A SUPPLEMENTAL CHAPTER

ON GLADSTONE'S "DAWN OF CREATION" AND "PROEM OF GENESIS," AND ON DRUMMOND'S "NATURAL LAW IN THE SPIRITUAL WORLD."

BY

S. LAING.

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PREFACE TO FIRST EDITION.

THE object of this book is to give a clear and concise view of the principal results of Modern Science, and of the revolution which they have effected in Modern Thought. I do not pretend to discover fresh facts or to propound new theories, but simply to discharge the humbler though still useful task of presenting what has become the common property of thinking minds, in a popular shape, which may interest those who lack time and opportunity for studying special subjects in more complete and technical treatises.

I have endeavored also to give unity to the subjects treated of, by connecting them with leading ideas: in the case of Science, that of the gradual progress from human standards to those of almost infinite space and duration, and the prevalence of law throughout the universe to the exclusion of supernatural interference; in the case of Thought, the bearings of these discoveries on old creeds and philosophies, and on the practical conduct of life. The endeavor to show how much of religion can be saved from the shipwreck of theology has been the main object of the second part. Those who are acquainted with the scientific literature of the day will at once see how much I have been indebted to Darwin, Lyell, Lubbock, Huxley, Proctor, and other well-known writers. In fact, the first part of this book does not pretend to be more than a compendious popular abridgment of their works. I

prefer, therefore, acknowledging my obligations to them once for all, rather than encumbering each page by detailed references.

The second part contains more of my own reflections on the important subjects discussed, and must stand or fall on its own merits rather than on authority. I can only say that I have endeavored to treat these subjects in a reverential spirit, and that the conclusions arrived at are the result of a conscientious and dispassionate endeavor to arrive at "the truth, the whole truth, and nothing but the truth."

S. LAING.

MODERN SCIENCE
AND
MODERN THOUGHT.

CHAPTER I.

SPACE.

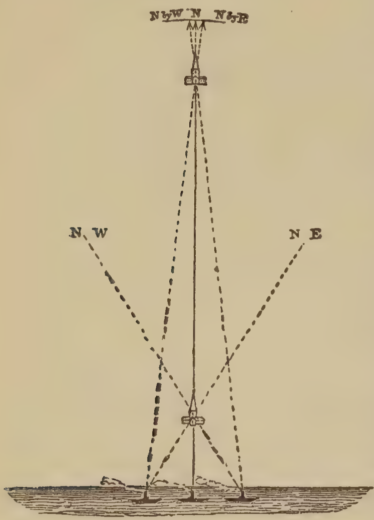
THE first ideas of space were naturally taken from the standard of man's own impressions. The inch, the foot, the cubit, were the lengths of portions of his own body, obviously adapted for measuring objects of comparatively small size with which he came in direct contact. The mile was the distance traversed in 1,000 double paces; the league the distance walked in an hour. The visible horizon suggested the idea that the earth was a flat, circular surface like a round table; and as experience showed that it extended beyond the limits of a single horizon, the conception was enlarged, and the size of the table increased so as to take in all the countries known to the geography of successive periods.

In like manner the sun, moon, and stars were taken to be at the distance at which they appeared; that is, first of the visible horizon, and then of the larger circle to which it had been found necessary to expand it. It was never doubted that they really revolved, as they seemed to do, round this flat earth circle, dipping under it in the west at night, and reappearing in the east with the day. The conception of the universe, therefore, was of a flat, circular earth surrounded by an ocean stream, in the centre of a crystal sphere which revolved in twenty-four hours round the earth, and in which the heavenly bodies were fixed as lights for man's use to distinguish days and seasons. The *maximum* idea of space was therefore determined by the size of the earth circle which was necessary to take in all the regions known at the time, with a little margin beyond for the ocean stream, and the space between it and the crystal vault, required to enable the latter to revolve freely. In the time of Homer and the early Greek philosophers, this would probably require a maximum of space of from 5,000 to 10,000 miles. This dimension has been expanded by modern science into one of as many millions, or rather hundreds of millions, as there were formerly single miles, and there is no sign that the limit has been reached.

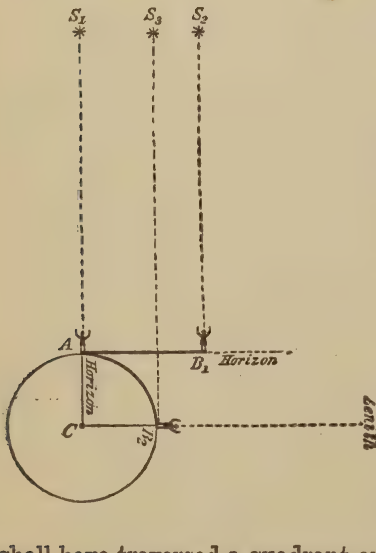
How has this wonderful result been arrived at, and how do we feel certain that it is true? Those who wish thoroughly to understand it must study standard works on Astronomy, but it may be possible to give some clear idea of the processes by which it has been arrived at, and of

the cogency of the reasoning by which we are compelled to accept facts so contrary to the first impressions of our natural senses.

The fundamental principle upon which all measurements of space depend, which are beyond the actual applicationtof human standards, is this: that distant objects change their bearings for a given change of base, more or less in proportion as they are less or more distant. Suppose I am on board a steamer sailing down the Thames, and I see two churches on the Essex coast directly opposite to me, or bearing due north, the first of which is one mile and the other ten miles distant. I sail one mile due east and again take the bearings. It is evident that the first church will now bear north-west, or have apparently moved through 45°, *i.e.*, one-eighth part of the circumference of a complete circle, assuming this circumference to be divided into 360 equal parts or degrees; while the more distant church will only have altered its bearing by a much less amount, easily determined by calculation, but which may be taken roughly at 5° instead of 45°.



The branch of mathematics known as Trigonometry enables us in all cases, without exception, where we know the apparent displacement or change of bearing of a distant object produced by taking it from the opposite ends of a known base, to calculate the distance of that object with as much ease and certainty as if we were working a simple sum of rule of three. The first step is to know our base, and for this purpose it is essential to know the size and form of the earth on which we live. These are determined by very simple considerations.



If I walk a mile in a straight line, an object at a vast distance like a star will not change its apparent place perceptibly. But if I walk the same distance in a semi-circle, what was originally on my left hand will now be on my right, or will have changed its apparent place by 180°. If I walk my mile on the circumference of a circle of twice the size, I shall have traversed a quadrant or one-fourth part of it, and changed the bearing of the distant object exactly half as much, or 90°, and so

on, according to the size of the circle, which may therefore be readily calculated from the length that must be travelled along it to shift the bearing of the remote object by a given amount, say of 1°.

If, for instance, by travelling 65 miles from north to south we lower the apparent height of the Pole star 1°, it is mathematically certain that we have travelled this 65 miles, not along a flat surface, but along a circle which is 360 times 65, or, in round numbers, 24,000 miles in circumference and 8,000 miles in diameter. And if, whenever we travel the same distance on a meridian or line drawn on the circumference from north to south, we find the same displacement of 1°, we may be sure that our journey has been in a true circle, and that the form of the earth is a perfect sphere of these dimensions.

Now, this is very nearly what actually occurs when we apply methods of scientific accuracy to measure the earth. The true form of the earth is not exactly spherical, but slightly oval or flatter at the poles, being almost precisely the form it would have assumed if it had been a fluid mass rotating about a north and south axis. But it is very nearly spherical, the true polar diameter being 7,899 miles, and the true equatorial diameter 7,925 miles, so that for practical purposes we may say roughly that the earth is a spherical body, 24,000 miles round and 8,000 miles across.

This gives us a fresh standard from which to start in measuring greater distances. Precisely as we inferred the distance of the church from the steamer in our first illustration, we can infer the distance of the sun, from its displacement caused by observing it from two opposite ends of a base of known length on the earth's surface. This is the essential principle of all the calculations, though, when great accuracy is sought for, very refined methods of applying the principle are required, turning mainly on the extent to which the apparent occurrence of the same event—such as the transit of Venus over the sun's disc—is altered by observing it from different points at known distances from one another on the earth's surface. The result is to show that the sun's distance from the earth is, in round numbers, 93,000,000 miles. This is not an exact statement, for the earth's orbit is not an exact circle, but the sun and earth really revolve in ellipses about the common centre of gravity. The sun, however, is so much larger than the earth that this centre of gravity falls within the sun's surface, and, practically, the earth describes an ellipse about the sun, the 93,000,000 miles being the mean distance, and the eccentricity, or deviation from the exact circular orbit, being about one-sixtieth part of that mean distance. This distance, again, gives us the size of the sun, for it is easily calculated how large the sun must be to look as large as it does at a distance of 93,000,000 miles. The result is, that it is a sphere of about 880,000 miles in diameter. Its bulk, therefore, exceeds that of the earth in the proportion of 1,384,000 to 1. Its density, or the quantity of matter in it, may be calculated from the effect of its action on the earth under the law of gravity at the distance of 93,000,000 miles. It weighs as much as 354,936 earths.

The same method gives us the distance, size, and weight of the moon and planets; and it gives us a fresh standard or base from which to measure still greater distances. The distance of the earth from the sun being 93,000,000 miles, and its orbit an ellipse nearly circular, it follows that it is in mid-winter, in round numbers, 186,000,000 miles distant from the spot where it was at mid-summer. What difference in

the bearings of the fixed stars is caused by traversing this enormous base?

The answer is, in the immense majority of cases, no difference at all; *i.e.*, their distance is so vastly greater than 186,000,000 miles that a change of base to this extent makes no change perceptible to the most refined instruments in their bearings as seen from the earth. But the perfection of modern instruments is such, that a change of even one second, or $\frac{1}{3600}$th part of one degree, in the annual parallax, as it is called, of any fixed star, would certainly be detected.

This corresponds to a distance of 206,265 times the length of the base of 186,000,000 miles, or of 20,000,000,000,000 miles, a distance which it would take light moving at the rate of 190,000 miles per second, three years and eighty-three day to traverse. There is only one star in the whole heavens, a bright star called Alpha, in the constellation of the Centaur, which is known to be as near as this. Its annual parallax is 0·976″, or very nearly 1″, and therefore its distance very nearly 20 millions of millions of miles. All the other stars, of which many millions are visible through powerful telescopes, are further off than this.

There are about eight other stars which have been supposed by astronomers to show some trace of an annual parallax of less than half a second, and therefore whose distances may be somewhere from twice to ten times as great as that of Alpha Centauri, and from the quantity of light sent to us from these distances, some approximation has been made to their intrinsic splendor as compared with our sun. That of Alpha Centauri is computed to be nearly $2\frac{1}{2}$ times that of Sirius, the brightest star in the heavens, 393 times greater than that of the sun. These figures may or may not represent greater size or greater intensity of light, and they are only quoted to give some idea of the vastness of the scale of the universe, of which our solar system forms a minute part.

Nor does even this nearly fathom the depth of the abysses of space. Telescopes enable us to see a vast multitude of stars of varying size and brilliancy. It is computed by astronomers that there are at least one hundred millions of stars within the range of the telescopes used by Herschel for gauging the depth of space, and a thousand millions within the range of the great reflecting telescope of Lord Rosse. As many as eighteen different orders of magnitude have been counted, and the more the power of telescopes is increased the more stars are seen. Now, as there is no reason to suppose that this extreme variety of brilliancy arises from extreme difference of size of one star from another, it must be principally owing to difference of distance, so that a star of the eighteenth magnitude is presumably many times further off than any of the first magnitude, the distance of the nearest of which has been proved to be something certainly not less than 20,000,000,000,000 miles. In fact, these stellar distances are so great that in order to bring them at all within the range of human imagination we are obliged to apply another standard, that of the velocity of light. Light can be shown to travel at the rate of about 186 millions of miles in 16 minutes, for this is the difference of the time at which we see the same periodical occurrence, as for instance the eclipses of Jupiter's satellites, according as the earth happens to be at the point of its orbit nearest to Jupiter or at that farthest away. The velocity of light is therefore about 184,000 miles per second, a velocity which has been fully confirmed by direct experiments made on the earth's surface.

These enormous distances are reckoned, therefore, by the number of years which it would take light to come from them, travelling as it does at the rate of 184,000 miles a second. The nearest fixed star, Alpha Centauri, is seen by the ray which left it three years and eighty-three days ago, and has been travelling ever since at the rate of 184,000 miles per second. Sirius, the brightest of the fixed stars, if the determination of its annual parallax is correct, is six times further off, and is seen, not as it exists to-day but as it existed nearly twenty years ago; and the light we now see from some of the stars of the eighteen magnitude can hardly have left them less than 2,000 years ago.

Even this, however, is far from exhausting our conception of the magnitude of space. Beyond the stars which are near enough to be seen separately, powerful telescopes show a galaxy in which the united lustre of myriads of stars is only perceptible as a faint nebulous gleam. And in addition to stars the telescope shows us a number of nebulæ, or faint patches of light, sometimes globular, sometimes in wreaths, spiral wisps, and other fantastic shapes, scattered about the heavens. Some of these are resolved by powerful telescopes into clusters of stars inconceivably numerous and remote, which appear to be separate universes, like that of which our sun and fixed stars form one. Others again cannot be so resolved, and are shown by the spectroscope to be enormous masses of glowing gas, or cosmic matter, out of which other universes are in process of formation.

We are thus led, step by step, to enlarge our ideas of space from the primitive conception of miles and leagues, until the imagination fails to grasp the infinite vastness of the scale upon which the material universe is really constructed.

If the telescope takes us thus far beyond the standards of unaided sense in the direction of the infinitely great, the microscope, aided by calculations as to the nature of light, heat, electricity, and chemical action, takes us as far in the opposite direction of the infinitely small. The microscope enables us actually to see magnitudes of the order of $\frac{1}{100,000}$th of an inch as clearly as the naked eye can see those of $\frac{1}{10}$th. This introduces us into a new world, where we can see a whole universe of things both dead and alive of whose existence our forefathers had no suspicion. A glass of water is seen to swarm with life, and be the abode of bacteria, amœbæ, rotifers, and other minute creatures, which dart about, feed, digest, and propagate their species in this small world of their own, very much as jelly-fish and other humble organisms do in the larger seas. The air also is shown to be full of innumerable germs and spores floating in it, and ready to be deposited and spring into life, wherever they find a seed-bed fitted to receive them. Given a favorable soil in the human frame, and the invisible seeds of scarlet fever, cholera, and small-pox ripen into full crops, just as the germs of a fungus invade the potato crops of a whole district, and lead to Irish famines and the extermination of more than a million of human beings.

The microscope also enables us to see the very beginnings of life and watch its primitive element, protoplasm, in the form of a minute speck of jelly-like matter, through which pulsations are constantly passing, and we can watch the transformations by which an elementary cell of this substance splits up, multiplies, and by a continued process of development builds up with these cells all the diversified forms of vegetable and animal life.

But far as the microscope carries us down to dimensions vastly

smaller than those of which the ordinary senses can take cognizance, the modern sciences of light, heat, and chemistry carry us as much farther downwards, as the telescope carries us upwards beyond the boundaries of our solar system into the expanses of stars and nebulæ. We are transported into a world of atoms, molecules, and light-waves, where the standard of measurement is no longer in feet or inches, or even in one-hundred-thousandth part of an inch, but in millionths of millimetres, *i. e.*, in $\frac{1}{25,000,000,000}$th of an inch. The dimensions are such that, as we shall see when we come to deal with matter, if the drop of water in which the microscope shows us living animalcula were magnified to the size of the earth, the atoms of which it is composed would appear of a size intermediate between that of a rifle-bullet and a cricket-ball.

This, then, is Nature's scale of space, from millionths of a millimetre up to millions of millions of miles. Throughout the whole of this enormous range of space the laws of Nature prevail.

Matter attracts matter by the same law of gravity in the case of double stars revolving about each other at a distance at which a base of 180,000,000 miles has long since become a vanishing point, and in the case of atoms which form the substance of a gas, as in that of an apple falling from a tree at the earth's surface. Comets, darting off into the remote regions of space, return after long periods, in obedience to the same law. Clouds of meteoric dust revolve in fixed orbits, determined by the law of gravity as surely as the moon revolves round the earth, and the earth round the sun.

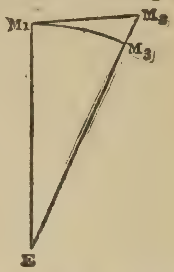
This is a conclusion of such fundamental importance that it is desirable to give the uninitiated reader some clear idea of what it means and how it is arrived at. Newton's great discovery, the law of gravity, is this—that all matter acting in the mass attracts other matter directly as the amount of attracting matter, and inversely as the square of the distance. That is, 2 or 2,000,000 tons attract with twice the force of 1 or 1,000,000 tons at the same distance, but with only one-fourth of the same force at double, and one-ninth at triple the distance.

How is this law proved? This will be best answered by explaining how it was discovered. The force of gravity, or attraction of the earth on bodies at the earth's surface, is a known quantity. The whole matter in a spherical body attracts exactly as if it were all collected at the centre. The force of gravity at the earth's surface is, therefore, that of the earth's mass exerted at a distance of about 4,000 miles, and this can be easily measured by observing the space fallen through, and the velocity acquired, by a falling body in a given time, such as 1″.

Does the same force act at the distance of the moon, or 207,200 miles? This was the question Newton asked himself, and the answer was got at in the following way. If we swing a stone in a sling round our head, it describes a circle as long as we keep the string tight, and its pull inwards just balances the pull of the stone to fly outwards, *i.e.*, to use scientific language, as long as the centripetal just balances the centrifugal force. But if we let go the string the stone darts off in the direction in which, and with the velocity with which, it was moving when the centripetal force ceased to act.

The moon is such a sling-stone revolving about the earth. At each instant it is moving in the direction of a tangent to its orbit, and would move on in a straight line along this tangent if it were not deflected from it by some other force. That is, if the moon were now

at M_1, it would, after a given interval of time, be at M_2 if no force had acted on it. But in point of fact it is not at M_2 but at M_3. Therefore it has been pulled down from M_2 to M_3, or if you like, fallen through the space $M_2 M_3$ in the time in which it would have travelled over $M_1 M_2$ with its velocity at M_1. How does this space correspond with the space through which a heavy body would have fallen in the same time at the earth's surface? It corresponds exactly, assuming the law of gravity to be, that it decreases with the square of the distance.



This may be taken as the first approximation, but the more accurate and universal proofs of the law are derived from mathematical calculations of what the nature of the attractions must be, in the case of the sun, earth, moon, and planets, to make them describe such elliptic orbits and observe such laws, as from Kepler's observations we know actually to be the case. The answer here again is the law of gravity, and no other possible law, and this is confirmed in practice by the fact that we are able, by calculations based on it, to satisfy the requisite of safe prophecy—that of knowing beforehand, and to predict eclipses, comets, transits, and occultations, and generally to compile Nautical Almanacs, by which ships know their whereabouts in pathless oceans.

This, then, affords us a first firm standing-point in any speculations as to the nature of the universe. One great law, at any rate, is universal throughout all space, and, as we shall see later, suns, stars, and nebulæ are composed of the same matter as the earth and its inhabitants.

In like manner comets and meteors, though presenting in other respects phenomena not yet fully understood, are proved to obey the same laws and to consist of the same matter. Comets are bodies which revolve round the sun, and are attracted by it and by the planets, in obedience to the ordinary law of gravity, though their density is so slight, that although often of enormous volume, they produce no perceptible effect on the planets, even when entangled amidst the satellites of a planet, as Lascelles' comet was among those of Jupiter.

Their dimensions may be judged of when it is stated that the comet of 1811 had a tail 120 millions of miles in length and 15 millions of miles in diameter at the widest part, while the diameter of the nucleus was about 127,000 miles, or more than ten times that of the earth. In order that bodies of this magnitude, passing near the earth, should not affect its motion or change the length of the year by even a single second, their actual substance must be inconceivably rare. If the tail, for instance, of the comet of 1843 had consisted of the lightest substance known to us, hydrogen gas, its mass would have exceeded that of the sun, and every planet would have been dragged from its orbit. As Proctor says, therefore: "A jar-full of air would probably have outweighed hundreds of cubic miles of that vast appendage which blazed across the skies to the terror of the ignorant and superstitious."

The extreme tenuity of a comet's mass is also proved by the phenomenon of the tail, which, as the comet approaches the sun, is thrown out sometimes to a length of 90 millions of miles in a few hours. And what is remarkable, this tail is thrown out against the force of gravity by some repulsive force, probably electrical, so that it always points away from the sun. Thus a comet which approaches the sun with a

tail behind it, will, after passing its perihelion, recede from the sun with its tail before it, and this although the tail may be of the length of 200 millions of miles as in the comet of 1843. In the course of a few hours, therefore, this enormous tail has been absorbed and a new one started out in an opposite direction. And yet, thin as the matter of comets must be, it obeys the common law of gravity, and whether the comet revolves in an orbit within that of the outer planets, or shoots off into the abysses of space and returns only after hundreds of years, its path is, at each instant, regulated by the same force as that which causes an apple to fall to the ground; and its matter, however attenuated, is ordinary matter, and does not consist of any unknown elements. The spectroscope shows that comets shine partly by reflected sunlight and partly by light of their own, the latter part being gaseous, and this gas, in most comets, contains carbon, hydrogen, and nitrogen, possibly also oxygen, in the form of hydrocarbons or marsh gas, cyanogen and possibly oxygen compounds of carbon. One comet has recently given the line of sodium, and the presence of iron is strongly suspected.

As regards meteors, which include shooting stars and aërolites, it has been long known, from actual masses which have fallen on the earth, that they are composed of terrestrial matter, principally of iron, which has been partially fused by the heat engendered by the fiction of the rapid passage through the air. The recurrence of brilliant displays at regular intervals, as for instance those of August and November, when the whole sky often seems alive with shooting stars, had also been noticed; but it was reserved for recent times to prove that these meteor streams are really composed of small planetary bodies revolving round the sun in fixed orbits by the force of gravity, and that their display, as seen by us, arises from the earth in its revolution round the sun happening to intersect some of these meteoric orbits, and the fiction of our atmosphere setting fire to and consuming the smaller meteors which appear as shooting stars. This shows the enormous number of meteors by which space must be tenanted. It is proved that the earth encounters more than a hundred meteor systems, but the chance of any one ring or system being intersected by the earth is extremely small, as the earth is such a minute speck in the whole sun-surrounding space of the solar system. On a scale on which the earth's orbit was represented by a circle of 10 feet diameter, the earth itself would be only about $\frac{1}{190}$th of an inch in diameter, so that if, as astronomers say, the earth encounters about a hundred meteor systems in the course of its annual revolution, space must swarm with an innumerable number of these minute bodies all revolving round the sun by the force of gravity.

Has this law of gravity been uniform through all time as it undoubtedly is through all space? We have every reason to believe so. The law of gravity, which is the foundation of most of what we call the natural laws of geological action, has certainly prevailed, as will be shown later, through the enormous periods of geological time, and far beyond this we can discern it operating in those astronomical changes by which cosmic matter has been condensed into nebulæ, nebulæ into suns throwing off planets, and planets throwing off satellites, as they cooled and contracted. We cannot speak with quite the same certainty of infinite time as we can of infinite space, for we have no telescopes to gauge the abysses of time, and no certain standards, like those of

the known dimensions of our solar system, to apply to periods too vast for the imagination.

But we can say this with certainty, that the present law of gravity must have prevailed when the outermost planet of our system, Neptune, was condensed into a separate body and began revolving in its present orbit, and that it has continued to act ever since; while, as a matter of probability, it is as nearly certain as anything can be, that the law by which the apple falls to the ground is an original law of matter, and has existed as long as matter has existed.

It certainly extends through all space. Double stars at a distance exceeding 20 millions of millions of miles revolve round their common centre of gravity by this law. Atoms and molecules almost infinitely smaller than millionths of millimetres derive from it their specific weights with as much certainty as if they were pounds or hundredweights.

What space and matter really may be, we do not know, and if we attempt to reason about their essence and origin, or quit the region of science based on fact, we get into the misty realms of metaphysics, where, like Milton's fallen angels, we

> Find no end in wandering mazes lost.

But this we do know of a certainty, that be matter and space what they may, they are subject to this one, uniform, all-pervading law; and attract, have always attracted, and will always attract, directly as the mass of the attracting matter and inversely as the square of the distance in space at which the attraction acts.

CHAPTER II.

TIME.

GEOLOGY has done for time what astronomy has for space—it has expanded the limited ideas derived from natural impression and early tradition, into those of an almost infinite duration. This result is so important that it is desirable that all educated persons, without being professed geologists, should have some clear idea of the nature of the conclusions and of the evidences on which they rest.

This I will endeavor to give.

When we come to examine the structure of the earth—or rather of the outer crust of the earth which we inhabit—with the care and precision of scientific methods, we find that it is not of uniform composition, but consists mainly of distinct layers, or strata, lying one over the other. This is true not only of the larger beds, or distinct formations, but of the details of each formation, many of which are built up as regularly as the layers of the Great Pyramid, while others are made up of layers no thicker than the leaves of a book.

Now consider what this fact of stratification implies. In the first place it implies deposit from water, for there is no other agency by which materials can be sorted out and thrown down in horizontal layers, while this agency is now doing the same thing every day and all over the world. The Rhone flows into the lake of Geneva a turbid stream, and flows out of it as clear as crystal. All the matter it brings

in is deposited at the bottom of the lake, and in course of time will fill it up. This deposit varies with every alternation of flood and drought; the river depositing sometimes boulders and coarse gravel, sometimes shingle, sand, or fine mud, and carrying this material sometimes to a greater and sometimes to a less distance, according to the velocity of the stream.

Ages hence, when the lake has been converted into dry land, it will be as certain, whenever a pit is dug or a well sunk in it, that it was the work of a river flowing into a lake, as it is to-day, when we can see them at work.

And what is true of the Rhone and the Lake of Geneva, is true on a larger scale of the Ganges, the Mississippi, and of every sea or ocean, with every river or torrent pouring into it.

Again, the sea is perpetually wearing away the coasts of all lands, and, where the cliffs are soft and the tides and currents strong, at a very rapid rate. The materials swallowed up are rolled as shingle, ground into sand, or floated as fine mud, and all finally assorted and laid down at the bottom of the sea, not in a confused heap, but in regular succession. On some of them, shell-fish and other marine creatures live and die for generations, and their remains are covered over by fresh sands or clays, and preserved for future geologists. All this is going on now, and when we examine the rocks we find that precisely the same sort of thing has been going on from the newest to the oldest strata. With the exception of a comparatively small amount of igneous rock, which has boiled up from deep sources of molten matter, and been poured out in sheets of lava, or masses of trap, porphyry, and granite, according to the amount of pressure it has undergone and the time it has taken to cool and crystallize, all the earth's surface may be said to consist of stratified matter, showing clear signs of having been deposited from water. Some of the oldest rocks, such as gneiss, may be a little doubtful, as they have clearly been subjected to great heat under great pressure, until they became plastic enough to crystallize as they cooled, and thus destroy any fossils embedded in them and obliterate most of the ordinary signs of stratification. But the opinion of the best geologists is that they were originally stratified, and have become what is called "metamorphic," or changed by heat and pressure into the semblance of igneous rocks. But even if these are not included, enough remains to justify the general assertion that the outer crust of the earth, as known to us, is made up mainly of stratified materials which have been deposited from water.

Now this implies another most important fact, viz., that there must have been waste or denudation of existing land corresponding to the deposit of stratified materials under water. Water cannot generate these materials, and every square mile of such strata, say 10 feet thick, implies the removal of 10 feet from a square mile of land surface by rains and rivers, or of an equivalent amount of cubical content in some other way, as by the erosion of a coast line. This is a very important consideration when we come to estimate the time required for the formation of such a thickness of stratified beds as we find existing. There must have been a fundamental crystalline rock as the earth cooled down from a fluid state and acquired a solid crust, and this rock must have been worn down by primeval seas and rivers as the progressive cooling admitted of the condensation of aqueous vapor into

water. The waste of this primitive crust must have been deposited in strata at the bottom of those seas in thick masses, covering the original rock, and these again must have been partly crystallized by heat and pressure, and over and over again upheaved and submerged, and themselves worn down by fresh erosion, forming fresh deposits which underwent a repetition of the same process.

A third important inference from the fact of stratification is that all strata must have been originally deposited horizontally, or very nearly so, and in such order that the lowest is the oldest.

Suppose we fill a jar with water, and put some white sand into it, and when that has subsided to the bottom and the water is clear, some yellow sand, and again some red sand, it is clear that we shall have at the bottom of the jar three horizontal deposits or strata, one white, one yellow, and one red, and that by no conceivable means can the order in which they were deposited have been other than first white, secondly yellow, and lastly red. This law, therefore, is invariable, that wherever it is possible to trace a series of strata lying one above the other, the lowest is the oldest, and the highest the youngest in point of time.

If, therefore, all the great formations, from the old Laurentian up to the newest Tertiary, had been deposited uniformly all over the world, and had remained undisturbed, and we could have seen them in one vertical section in a cliff twenty-five miles high—for that is about their total known thickness—we should have been able without further difficulty to determine their order of succession and respective magnitudes.

But this is plainly impossible, for the deposits going on at any one time are of very different character. For instance, we have at present the Globigerina ooze gradually filling the depths of the Atlantic with a deposit resembling chalk; the Gulfs of Bengal and Mexico silting up with fine clay from river deposits; vast tracts in the Pacific, Indian Ocean, and Red Sea, covered with coral and the *débris* of coral-reefs. How could these, if upheaved into dry land and explored by future geologists, be identified as having been formed contemporaneously?

Suppose that coins of Victoria had been dropped in each of them, the geologist who discovered these coins would have no difficulty in concluding that the strata in which they were found were all formed in the nineteenth century. The petrified shells and other remains found in geological strata are such coins. Every great formation has had its own characteristic fauna and flora, or aggregate of animal and vegetable life, varying slowly from one geological age to another, and linked to the past and future by some persistent types and forms, but still with such a preponderance of characteristic fossils as to enable us to assign the rocks in which they occur to their proper place in the volume of the geological record. Innumerable observations have shown that we can rely, with absolute confidence, on the fossils embedded in the different strata of the earth's crust as tests of the period to which they belong, however different the strata may be in mineral composition.

The next question is how we can ascertain the thickness and order of succession of these strata. We have seen that all stratified rocks were originally deposited from water and therefore horizontally. Had they remained so, in the first place the process of forming strati-

fied rocks must long ago have come to an end, for all the land surface must have been worn down to the sea level, and with no more land to be denuded, deposition must have ceased at an early period of the earth's history. And, in the second place, we could have known nothing more of the earth's crust than we saw on the surface, and in the shallow pits and borings we could sink below it. But earthquakes and volcanoes, and the various fractures and pressures due to subterranean heat and secular contraction and cooling, have been at work counteracting the effects of denudation, and causing elevations and depressions by which the inequalities of the earth's surface have been renewed, the balance between sea and land maintained, and strata, originally horizontal at the bottom of the ocean, upheaved until sea-shells are found at the top of high mountains, and we can walk for miles over their upturned edges.

Any one who wishes to understand how geologists have been able to measure such a thickness of the earth's crust, has only to take a book open at page 1 and lay it flat before him. He can see nothing but that one page; but if he turns up the pages on the right-hand side of the book until their edges become horizontal, he can pass over them and count perhaps 500 pages in the space of a couple of inches.

This is precisely what geologists have been able to do at various points of the earth's surface where the upturned edges of the pages of its history are exposed, and they come out, one behind the other, in the due succession in which they were written by Nature. For instance, in travelling from east to west in England we pass continually from newer to older formations—Chalk comes in from below Tertiary; Oolite and Lias from below Chalk; then Permian or New Red Sandstone; Carboniferous, including the Coal measures; Devonian or Old Red Sandstone; Silurian, Cambrian, and in the extreme north-west of Scotland and the Hebrides, oldest of all the Laurentian.

There are some omissions and interpolations, but, in a general way, it may be said that within the bounds of the British Empire we have such a view of Nature's volume as would be got, in the case I have supposed, by travelling over its upturned edges from page 1 to page 500. And if each of the great formations be taken as a separate chapter, each chapter will be found to be made up of a number of pages, each with its own letter-press and illustrations, though connected with the pages before and after it by the thread of the continuous common subject of their proper chapter; as the chapters again are connected by the continuous common subject-matter of the complete volume. It must not be supposed that the volume is anything like perfect. We have to piece it together from fragments found in the limited number of countries which have thus far been scientifically explored, and which do not constitute more than a small part of the earth's surface. We know nothing of what is below the oceans which cover three-fourths of that surface, and there are great gaps in the record during times when portions of the surface were dry land, and consequently no deposit of strata or preservation of fossils was possible. Still a great deal has been accomplished, and the general result, as given by common consent of the best geologists, is as follows:

The total thickness of known strata is about 130,000 feet or twenty-five miles, or the $\frac{1}{160}$th part of the distance from the earth's surface to its centre. Of this, about 30,000 feet belong to the Laurentian, which is the oldest known stratified deposit; 18,000 to the Cambrian, and

22,000 to the Silurian. These form together what is known as the Primary or Palæozoic Epoch.

In the lowest, the Laurentian, the only faint trace of life discovered is that of the Eozoon Canadense, which is considered to be an undoubted petrifaction of a foraminiferous living organism with a chambered shell.

It must be remembered, however, that these earliest formations have been so changed by slow crystallization under great heat and pressure that all fossils and nearly all traces of stratification must have been obliterated.

In the Cambrian and Lower Silurian traces of life become more frequent, especially of low forms of sea-weeds, and in the Upper Silurian we find an abundance of life, consisting of crustacea, shell-fish, and a few true fish in the upper strata. Some of these shells, as the Lingula, have continued without much change up to the present time; and on the whole we find ourselves in the Silurian period, if not earlier, in presence of a state of things in which substantially present causes operated and present conditions were in force. Rains fell, winds blew, rivers ran, waves eroded cliffs, shell-fish lived and died, and crabs and sand-worms crawled about on shores left dry by each tide, very much as is the case at present.

The next great divison, which got the name of Primary before the existence of fossils was known in the older or Palæozoic division, comprises the Devonian or Old Red Sandstone; the Carboniferous which includes the coal; and the Permian or New Red Sandstone. The average thickness of these three systems taken together is about 42,000 feet. It may be called the era of Fern Forests and of Fish, the former being the principal source of our supplies of coal, and the latter being extremely abundant within the Devonian and Permian formations.

The third great division is formed by the Secondary group, which includes the Triassic, the Jura, and the Cretaceous or Chalk systems, and has an average thickness of about 15,000 feet. This epoch is emphatically the age of Reptiles as the preceding one was that of Fish, and the prevailing vegetation is no longer one of ferns and mosses, but of Gymnosperms, or plants having naked seeds, the most important class of which is that of the Coniferæ or Pine tribe. During this period the Plesiosauri, Ichthyosauri, and other gigantic sea-dragons abounded in the oceans; colossal land-dragons, such as the Dinosauri, occupied the continents, and Pterodactyls, a remarkable form of carnivorous flying lizards, ruled the air. Swarms of other reptiles, nearly related to the present lizards, crocodiles, and turtles, abounded both in the sea and land. A few traces of mammals and birds show that these orders had then come into existence, just as a few traces of reptiles are found in the Primary and of fish in the Palæozoic strata, but the few mammalian remains found are of small animals of the marsupial or lowest type, and the birds are of a transition type between reptiles and true birds. This epoch concludes with the Chalk formation, which is one of deep-sea deposit, where no trace of terrestrial life can be expected.

Above this comes the Tertiary epoch, when the present order, both of vegetable and animal life, is fairly inaugurated; mammals predominate over other forms of vertebrate animals; existing order, and species begin to appear and increase rapidly; and vegetation

consists mainly of Angiosperms, or plants with covered seeds, as in our present forests. The total thickness of these strata, from the lowest or Eocene, to the end of the uppermost or Pliocene, is about 3,000 feet. Above this comes the Quarternary, or recent period, which comprises the superficial strata of modern formation, and is characterized by the undoubted existence of man and of animal species, which either now exist or have become extinct in quite recent geological times.

The details of this and of the Tertiary Epoch will be more fully considered when we come to treat of the antiquity of man, with which they are closely connected. But for the present object, which is that of ascertaining some standard of time for the immense series of ages proved by geology to have elapsed since the earth assumed its present condition, became subject to existing laws and fitted to be the abode of life, it will be sufficient to refer to the older strata.

The best idea of the enormous intervals of time required for geological changes will be derived from the coal measures. These consist of part only of one geological formation known as the Carboniferous. They are made up of sheets or seams of condensed vegetable matter, varying in thickness from less than an inch to as much as thirty feet, and lying one above another, separated by beds of rocks of various composition. As a rule, every seam of coal rests upon a bed of clay, known as the "under-clay," and is covered by a bed of sandstone or shale. These alternations of clay, coal, and rock, are often repeated a great many times, and in some sections in South Wales and Nova Scotia, there are as many as eighty or a hundred seams of coal, each with its own under-clay below and sandstone or shale above. Some of the coal seams are as much as thirty feet thick, and the total thickness of the coal measures is, in some cases, as much as 14,000 feet.

Now consider what these facts mean. Every under-clay was clearly once a surface soil on which the forest vegetation grew, whose accumulated *débris* forms the overlying seam of coal. The under-clays are full of the fibres of roots, and the stools of trees which once grew on them, are constantly found *in situ*, with their roots attached just as they stood when the tree fell, and added to the accumulation of vegetable matter, which in modern times forms peat, and in more ancient days, under different conditions of heat and pressure, took the more consolidated form of coal.

When these vegetable remains are examined with the aid of the microscope it is found that these ancient forests consisted mainly of trees like gigantic club-mosses, mares'-tails, and tree ferns, with a few resembling yews and firs. But in many cases the bulk of the coal is composed of the spores and seeds of these ferns and club-mosses, which were ripened and shed every year, and gradually accumulated into a vegetable mould, just as fallen leaves, beech-mast, and other *débris* gradually form a soil in our existing forests.

The time required must have been very great to accumulate vegetable matter, principally composed of fine spore dust, to a depth sufficient under great compression to give even a foot of solid coal. Dr. Dawson, who has devoted great attention to the coal-fields of America, says: "We may safely assert that every foot of thickness of pure bituminous coal implies the quiet growth and fall of at least fifty generations of Sigillaria, and therefore an undisturbed condition of

forest growth, enduring through many centuries." But this is only the first step in the measure of the time required for the formation of the coal measures. Each seam of coal is, as we have seen, covered by a bed of sand or shale, *i. e.*, of water-borne materials. How can this be accounted for? Evidently in one way only—that the land surface in which the forest grew subsided gradually until it became first a marsh, and then a lagoon or shallow estuary, which silted up by degrees with deposits of sand or mud, and, finally, was upraised until its surface became dry land, in which a second forest grew, whose *débris* formed a second coal seam. And so on, over and over again, until the whole series of coal measures had been accumulated, when this alternation of slight submergences and slight rises came to an end, and some more decided movement of the earth's surface in the locality brought on a different state of things. This is in fact exactly what we see taking place on a smaller scale in recent times in such deposits as those of the delta of the Mississippi, where a well sunk at New Orleans passes through a succession of cypress swamps and forest growths, exactly like those now growing on the surface, which are piled one above the other, and separated by deposits of river silt, showing a long alternation of periods of rest when forests grew, followed by periods of subsidence when they were flooded and their remains were embedded in silt.

Starting on Dr. Dawson's assumption that one foot of coal represents fifty generations of coal plants, and that each generation of coal plants took ten years to come to maturity, an assumption which is certainly very moderate, and taking the actually measured thickness of the coal measures in some localities at 12,000 feet, Professor Huxley calculates that the time represented by the Coal formation alone would be six millions of years. Such a figure is, of course, only a rough approximation, but it is sufficient to show that when we come to deal with geological time, the standard by which we must measure is one of which the unit is a million of years.

This standard is confirmed by a variety of other considerations. Take the case of the Chalk formation.

Chalk is almost entirely composed of the microscopic shells of minute organisms, such as now float in the upper strata of our great oceans, and by their subsidence, in the form of an impalpable shell-dust, accumulate what is called the "Globigerina ooze," which is brought up by soundings in the Atlantic and Pacific from great depths. In fact, we may say that a chalk formation is now going on in the depths of existing oceans, and conversely that the old chalk, which now forms hills and elevated downs, was certainly deposited at the bottom of similar deep oceans of the Cretaceous period. The rate of deposit must have been extremely slow, certainly much slower than that of the deposit of the much grosser matter brought down by the Nile in its annual inundations, the growth of which has been estimated from actual measurement at about three inches per century. If one inch per century were the rate of accumulation of this microscopic shell-dust, subsiding slowly to depths of two or three miles over areas as large as Europe, it would take 1,200 years to form a foot of chalk, and 1,200,000 years to form 1,000 feet. Now there are places where the thickness of the Cretaceous formation, exposed by the edges of its upturned strata, exceeds 5,000 feet, so that this gives an approximation very similar to that furnished by the coal measures.

We have thus, on a rough approximation, a *minimum* period of about 6,000,000 years for the accumulation of a single member of one of the separate formations into which the total 130,000 feet of measured strata are subdivided. But this takes no account of the long periods during which no accumulation took place at the localities in question, and of the long pauses which must have ensued between each movement of elevation and submergence, and especially between the disappearance of an old and appearance of an almost entirely new epoch, with different forms of animal and vegetable life. We may be certain also that we are far from knowing the total thickness of strata which will be disclosed when the whole surface of the earth comes to be explored. All we can say is that we have fragmentary pages left in the geological record for, at the very least, 100 millions of years, and that probably the lost pages are quite as numerous as those of which we have an imperfect knowledge.

Sir Charles Lyell, the highest authority on the subject, is inclined to estimate the *minimum* of geological time at 200 millions of years, and few geologists will say that his estimate appears excessive.

Another test of the vast duration of geological time is afforded by the oscillations of the earth's surface. At first sight we are apt to consider the earth as the stable and the sea as the unstable element. But in reality it is exactly the reverse. Land has been perpetually rising and falling while the level of the sea has remained the same. This is easily proved by the presence of sea-shells and other marine remains in strata which now form high mountains. In the case of chalk, for instance, there must have been in England a change of relative level of sea and land or more than two miles of vertical height, between the original formation of the chalk at the bottom of a deep ocean and its present position in the North and South Downs. In other cases the change of level is even more conspicuous. The Nummulite limestone, which is formed like chalk from an accumulation of the minute shells of low organisms floating in the oceans of the early Tertiary period, is found in mountain masses, and has been elevated to a height of 10,000 feet and more in the Alps and Himalayas.

On a smaller scale, and in more recent times, raised beaches with existing shells and lines of cliffs and caves, are found at various heights above the existing sea-level of many of the coasts of Britain, Scandinavia, Italy, South America, and other countries.

Now the first question is, were these changes caused by the land rising or by the sea falling? The answer is, by the land rising Had they been caused by the sea standing at a higher level it must have stood everywhere at this level, at any rate in the same hemisphere and anywhere near the same latitude. But there are large tracts of land which have never been submerged since remote geological periods; and in recent times there is conclusive evidence that the changes of level of sea and land have been partial and not general. Thus in the well-known instance of the columns of the ruined temple of Serapis at Pozzuoli in the Bay of Naples, which forms the illustration on the title-page of Lyell's "Principles of Geology," there can be no doubt that since the temple was built, either the sea must have risen and since fallen, or the land sunk and since risen, at least twenty feet since the temple was built less than 2,000 years ago, for up to this height the marble columns are riddled by borings of marine shells, whose valves

are still to be seen in the holes they excavated. But an elevation of the level of the Mediterranean of twenty feet would have submerged a great part of Egypt, and other low-lying lands on the borders of that sea, where we know that no such irruptions of salt water have taken place within historical, or even within recent geological times.

The conclusion is therefore certain, that the land at this particular spot must have sunk twenty feet, and again risen as much, so as to bring back the floor of the temple to its present position, which stood one hundred years ago just above the sea-level, and that so gradually as not to throw down the three columns which are still standing. A slow subsidence has since set in and is now going on, so that the floor is now two or three feet below the sea-level.

Similar proofs may be multiplied to any extent. Along the coasts of the British Islands we find, in some places submarine forests showing subsidence, in others raised beaches showing elevation, but they are not continuous at the same level. Along the east coast of Scotland there is a remarkable raised beach at a level of about twenty-four feet above the present one, showing in many places lines of cliff, sea-worn caves, and outlying stacks and skerries, exactly like those of the present coast, though with green fields or sandy links at their base, instead of the waves of the German Ocean. But as we go north this inland cliff gets lower and gradually dies out, and when we get into the extreme north, among the Orkney and Shetland Islands, there are no signs of raised beaches, and everything points towards the recent period having been one of subsidence.

Again, in Sweden, where marks were cut in rocks in sheltered situations on the tideless Baltic more than a century ago, so as to test the question of an alleged elevation of the land, it has been clearly shown that, in the extreme north of Sweden, the marks have risen nearly seven feet, while in the central portion of the country they have neither risen nor fallen, and in the southern province of Scania they have fallen.

This would be clearly impossible if the sea and not the land had been the unstable element, and apparent elevations and depressions had been due to a general fall or rise in the level of all the seas of the northern hemisphere.

In fact, the more we study geology the more we are impressed with the fact that the normal state of the earth is, and has always been, one of incessant changes. Water, raised by evaporation from the seas, falls as rain or snow on land, wastes it away and carries it down from higher to lower levels, to be ultimately deposited at the bottom of the sea. This goes on constantly, and if there were no compensating action, as the seas cover a much larger area than the lands, all land would ultimately disappear, and one universal ocean cover the globe. But inward heat supplies the compensating action, and new lands rise and new mountain chains are upheaved to supply the place of those which disappear.

This inward heat of the earth is not a mere theory but an ascertained fact; for as we descend from the surface in deep mines or borings, we find the temperature actually does increase at a rate which varies somewhat in different localities, but which averages about 1° Fahrenheit for every 60 feet of depth. At this rate of increase water would boil at a depth of 10,000 feet, and iron and all other metals be melted before we reached 100,000 feet. What actually occurs at great

depths we do not know with any certainty, for we are not sufficiently acquainted with the laws under which matter may behave when under enormous heat combined with enormous pressure. But we do know from volcanoes and earthquakes that masses of molten rocks and of imprisoned gases exist in certain localities, at depths below the surface which, although large compared with our deepest pits, are almost infinitesimally small compared with the total depth of 4,000 miles from that surface to the earth's centre.

This much is clear, that, in order to account for observed facts, we must consider the extreme outer crust, or surface of the earth as known to us, as resting on something which is liable to expand and contract slowly with variations of heat, and occasionally, when the tension becomes great, to give violent shocks to the outer crust, sending earthquake waves through it, and to send up gases and molten lava through volcanoes, along lines of fissure, and at points of least resistance. It is clear, also, that these movements are not uniform, but that one part of the earth's surface may be rising while another is sinking, and portions of it may be slowly tilting over, so that as one end sinks the other rises.

The best comparison that can be made is to a sheet of ice which has been much skated over and cracked in numerous directions, so as to have become a sort of mosaic of ice fragment, which, when a thaw sets in and the ice gets sloppy, rise and fall with slightly different motions as a skater, gliding over them, varies the pressure, and occasionally give a crack and let water rise through from below in the line of fissure. The difficulty will not seem so great if we consider that the rocks which form the earth's crust are for the most part elastic, and that an amount of elevation which seems large in itself does not necessarily imply a very steep gradient. Thus, if the elevation which towards the close of the Glacial period carried a bed of existing sea-shells of Arctic type to the top of the hill, Moel Tryfen, in North Wales, which is 1,200 feet high, were, say one of 1,500 feet, this would be given by a gradient of 15 feet a mile, or 1 in 333 for 100 miles. Such a gradient would not be perceptible to the eye, and would certainly not be sufficient to cause any tension likely to rupture rocks or disturb strata.

Such movements are as a rule extremely slow. In volcanic regions there are occasionally shocks which raise extensive regions a few feet at a blow, and partial elevations and subsidences which throw up cones of lava and cinders, or let mountains down into chasms, in a single explosion. The most noted of these are the instances of Monte Nuovo, near Naples, 800 feet high, and Jorullo, in Mexico, thrown up in one eruption, and the disappearance the other day of a mountain 2,000 feet high in the Straits of Sunda during an earthquake. The largest rise recorded of an extensive area from the shock of an earthquake, is that which occured in South America in 1835, when a range of coast of 500 miles from Copiapo to Chiloe was permanently raised five or six feet by a single shock, as was shown by the beds of dead mussels and other shells which had been hoisted up in some places as much as ten feet. It is probable that the great chain of the Andes, whose highest summits reach 27,000 feet, has been raised in a great measure by a succession of similar shocks.

But for the most part these movements, whether of elevation or depression, go on so slowly and quietly that they escape observation

Scandinavia is apparently now rising and Greenland sinking, but most countries have remained appreciably steady, or nearly so, during the historical period. St. Michael's Mount, in Cornwall, is still connected with the mainland by a spit, dry at ebb tide and covered at flood, as it was more than 2,000 years ago when the old Britons carted their tin across to Phœnician traders. Egypt, during a period of 7,000 years, has preserved the same level, or at the most has sunk as slowly as the Nile mud has accumulated. Parts of the English and Scotch coast have risen perhaps twenty feet since the prehistoric period, when canoes were wrecked under what are now the streets of Glasgow, and whales were stranded in the Carse of Stirling. There is even some evidence that the latest rise may have occurred since the Roman wall was built from the Forth to the Clyde. In any case, however, the movements have been extremely slow, and there have been frequent oscillations, and long pauses when the level of land and sea remained stationary. The evidence, therefore, from the great changes which have occurred during each geological period, points to the same conclusion as that drawn from the thickness of formations, such as the coal measures and chalk, which must have been accumulated very slowly, viz., that geological time must be measured by a scale of millions of years.

Another test of the vast duration of geological time is afforded by the changes which have taken place in animal life as we pass from one formation to another, and even within the limits of the same formation. The fauna, or form of existing life at a given period, changes with extreme slowness. During the historical period there has been no perceptible change, and even since the Pliocene period, which cannot be placed at a less distance from us than 200,000 years, and probably at much more, the change has been very small. In the limited class of large land animals it has been considerable; but if we take the far more numerous forms of shell-fish and other marine life, the old species which have become extinct and the new ones which have appeared, do not exceed five per cent. of the whole. This is the more remarkable as great vicissitudes of climate and variations of sea-level have occurred during the interval. The whole of the Glacial period has come and gone, and Britain has been by turns an archipelago of frozen islands, and part of a continent extending over what is now the German Ocean, and pushing out into the Atlantic up to the one hundred fathom line.

Reasoning from these facts, assuming the rate of change in the forms of life to have been the same formerly, and summing up the many complete changes of fauna which have occurred during the separate geological formations, Lyell has arrived at the conclusion that geology requires a period of not less than 200 millions of years to account for the phenomena which it discloses.

Long as the record is of geological time, it is only that of one short chapter in the volume of the history of the universe. Geology only begins when the earth had cooled down into a state resembling the present; when winds blew, rains fell, rivers and seas eroded rocks and formed deposits, and when the conditions were such that life became possible by the remains of which those deposits can be identified.

But before this period began, which may be called that of the maturity or middle age of our planet, a much vaster time must be allowed for the contraction and cooling of the vaporous ether or cosmic matter of which it is formed, into the state in which the

phenomena of geology became possible. And if vast in the case of the earth, how must vaster must be the life periods of the larger planets, such as Jupiter, which from their much greater size cool and contract much more slowly, and are not yet advanced beyond the stage of intense youthful heat and glowing luminosity which was left behind by our earth a great many tens of millions of years ago! And how vastly vaster must be that of the sun, whose mass and volume exceed those of Jupiter in a far higher ratio than Jupiter surpasses the earth!

And beyond all this in a third degree of vastness come the life periods of those stars or distant suns, which we know to be in some cases as much as three hundred times larger than our sun, and not nearly so far advanced as it in the process of emergence from the fiery nebulous into the solar stage.

To give some idea of the vast intervals of time required for these changes, a few facts and figures may be given.

One of the latest speculations of mathematical science is that the rotation of the earth is becoming slower, or in other words the day becoming longer, owing to the retarding action of the tides, which act as a brake on a revolving wheel. If so, mathematical calculation shows that the effect of the reaction on the moon of this action of the moon on the earth, must be that as the earth rotates more slowly, the moon recedes to a greater distance. And *vice versâ*, when the earth rotated more rapidly the moon was nearer to it, until at length, when the process is carried back far enough, we arrive at a time when the moon was at the earth's surface and the length of the day about three hours. In this state of things the moon is supposed to have been thrown off from the earth, either by one great convulsion, or, more probably, by small masses at a time forming a ring like that of Saturn, which ended by coalescing into a single satellite. With the moon, which is the principal cause of the tides, so much nearer the earth, their rise and fall must have been something enormous, and huge tidal waves like the bore of the Bay of Fundy, but perhaps 500 or 1,000 feet high, must have swept twice during each revolution of the earth on its axis, *i.e.*, twice every three or four hours, along all the narrower seas and channels and over all except the mountainous lands adjoining.

Now these conclusions may be true or not as regards phases of the earth's life prior to the Silurian period, from which downwards geology shows unmistakably that nothing of the sort, or in the least degree approaching to it, has occurred. But what I wish to point out is that all this superstructure of theory rests on a basis which really does admit of definite demonstration and calculation.

Halley found that when eclipses of the sun, recorded in ancient annals, are compared with recent observations, a discrepancy is discovered in the rate of the moon's motion, which must have been slightly slower then than it is now. Laplace apparently solved the difficulty by showing that this was an inevitable result of the law of gravity, when the varying eccentricity of the earth's orbit was properly taken into account; and the calculated amount of the variation from this cause was shown to be exactly what was required to reconcile the observations. But our great English mathematician, Adams, having recently gone over Laplace's calculations anew, discovered that some factors in the problem had been omitted, which reduced Laplace's acceleration of

the moon's motion by about one-half, leaving the other half to be explained by a real increase in the length of the sidereal day, or time of one complete revolution of the earth about its axis. The retardation required is one sufficient to account for the total accumulated loss of an hour and a quarter in 2,000 years; or in other words, the length of the day is now more by about $\frac{1}{84}$th part of a second than it was 2,000 years ago.

At this rate it would require 168,000 years to make a difference of 1 second in the length of the day; 10,080,000 years for a difference of 1 minute; and 604,800,000 years for a difference of 1 hour. The rate would not be uniform for the past, for as the moon got nearer it would cause higher tides and more retardation; still, the abyss of time seems almost inconceivable to get back to the state in which the earth could have rotated in three hours and thrown off the moon.

It is right, however, to state that all mathematical calculations of time, based on the assumed rate at which cosmic matter cools into suns and planets, and these into solid and habitable globes, are in the highest degree uncertain. If the original data are right, mathematical calculation inevitably gives right conclusions. But if the data are wrong, or what is the same thing, partial and imperfect, the conclusions will, with equal certainty, be wrong also. Now in this case we certainly do not know "the truth, the whole truth, and nothing but the truth" respecting these processes. Take what is perhaps the most difficult problem presented by science—how the sun keeps up so uniformly the enormous amount of heat which it is constantly radiating into space. This radiation is going on in every direction, and the solar heat received by the earth is only that minute portion of it which is intercepted by our little speck of a planet. All the planets together receive less than one 230,000,000th part of the total heat radiated away by the sun and apparently lost in space. Knowing the amount of heat from the sun's rays received at the earth's surface in a given time, we can calculate the total amount of heat radiated from the sun in that time. It amounts to this, that the sun in each second of time parts with as much heat as would be given out by the burning of 16,436 millions of millions of tons of the best anthracite coal. And radiation certainly at this rate, if not a higher one, has been going on ever since the commencement of the geological record, which must certainly be reckoned by a great many tens of millions of years.

What an illustration does this afford of that apparent "waste of Nature" which made Tennyson "falter where he firmly trod" when he came to consider "her secret meaning in her deeds!"

Yet there can be no doubt that vast as these figures are, they are all the result of natural laws, just as we find the law of gravity prevailing throughout space at distances expressed by figures equally vast. The question is, what laws? The only one we know of at present at all adequate to account for such a generation of heat, is the transformation into heat of the enormous amount of mechanical force or energy, resulting from the condensation of the mass of nebulous matter from which the sun was formed, into a mass of its present dimensions. This is no doubt a true cause as far as it goes. It is true that as the mass contracts, heat would be, so to speak, squeezed out of it, very much as water is squeezed out of a wet sponge by compressing it. But it is a question whether it is the sole and sufficient cause. Mathematicians have calculated that even if we

suppose the original cosmic matter to have had an infinite extension, its condensation into the present sum would only have been sufficient to keep up the actual supply of solar heat for about 15 millions of years. Of this a large portion must have been exhausted before the earth was formed as a separate planet, and had cooled down into a habitable globe. But even if we took the whole it would be altogether insufficient. All competent geologists are agreed in requiring at least 100 millions of years to account for the changes which have taken place in the earth's surface since the first dawn of life recorded in the older rocks.

Various attempts have been made to reconcile the discrepancy. For instance, it has been said that the constantly repeated impact of masses of meteoric and cometic matter falling into the sun must have caused the destruction of a vast amount of mechanical energy which would be converted into heat. This is true as far as it goes, but it is impossible to conceive of the sun as a target kept at a perpetual and uniform white heat for millions of years by a rain of meteoric bullets constantly fired upon it. More plausibly it is said that we know nothing of the interior constitution of the sun, and that its solid nucleus may be vastly more compressed than is inferred from the dimensions of its visible disc, which is composed of glowing flames and vapors. This also may be a true cause, but, after making every allowance, we must fall back on the statement that the continuance for such enormous periods of such an enormous waste of energy as is given out by the sun, though certainly explainable by laws of Nature, depends on laws not yet thoroughly understood and explained.

Even in the case, comparatively small and near to us, of the earth, the condition of the interior and the rate of secular cooling afford problems which as yet wait for solution. The result of a number of careful experiments in mines and deep sinkings shows that the temperature, as we descend below the shallow superficial crust which is affected by the seasons, *i. e.*, by the solar radiation, increases at the average rate of 1° Fahrenheit for every 60 feet of depth. That is the average rate, though it varies a good deal in different localities. Now, at this rate we should soon reach a depth at which all known substances would be melted.

But astronomical considerations, derived from the Precession of the Equinoxes, favor the idea that the earth is a solid and not a fluid body, and require us in any case to assume a rigid crust of not less than ninety miles in thickness. And if the whole earth below a thin superficial crust were in an ordinary state of fluidity from heat, it is difficult to see how it could do otherwise than boil, that is, establishing circulating currents throughout its mass with disengagement of vapor, in which case the surface crust must be very soon broken up and melted down, just as the superficial crust of a red-hot stream of lava is, if an infusion of fresh lava raises the stream below to white heat, or as a thin film of ice would be if boiling water were poured in below it.

All we can say is, that the laws under which matter behaves under conditions of heat, pressure, chemical action, and electricity so totally different as must prevail in the interior of the earth, and *á fortiori* in that of the sun, are as yet very partially known to us. In the meantime the safest course is to hold by those conclusions of geology which, as far as they go, depend on laws really known to us. For instance, the quantity of mud carried down in a year by the Ganges or Missis-

sippi, is a quantity which can be calculated within certain approximate limits. We can tell with certainty how much the deposit of this amount of mud would raise an area, say of 100 square miles, and how long it would take, at this rate, to lower the area of India drained by the Ganges, a sufficient number of feet to give matter enough to fill up the Gulf of Bengal. And if among the older formations we find one, like the Wealden for instance, similar in character to that now forming by the Ganges, we can approximate from its thickness to the time that may have been required to form it.

In calculations of this sort there is no *theory*, they are based on positive facts, limited only by a certain possible amount of error either way. In short, the conclusions of geology, at any rate up to the Silurian period when the present order of things was fairly inaugurated, are approximate *facts* and not *theories*, while the astronomical conclusions are *theories* based on *data* so uncertain, that while in some cases they give results incredibly short, like that of 15 millions of years for the whole past process of the formation of the solar system, in others they give results almost incredibly long, as in that which supposes the moon to have been thrown off when the earth was rotating in three hours, while the utmost actual retardation claimed from observation would require 600 millions of years to make it rotate in twenty-three hours instead of twenty-four.

To one who looks at these discussions between geologists and astronomers not from the point of view of a specialist in either science, but from that of a dispassionate spectator, the safest course, in the present state of our knowledge, seems to be to assume that geology really proves the duration of the present order of things to have been somewhere over 100 millions of years, and that astronomy gives an enormous though unknown time beyond in the past, and to come in the future, for the birth, growth, maturity, decline, and death of the solar system of which our earth is a small planet now passing through the habitable phase.

So far, however, as the immediate object of this work is concerned, viz., the bearings of modern scientific discovery on modern thought, it is not very material whether the shortest or longest possible standards of time are adopted. The conclusions as to man's position in the universe and the historical truth or falsehood of old beliefs, are the same whether man has existed in a state of constant though slow progression for the last 50,000 years of a period of 15 millions, or for the last 500,000 years of a period of 150 millions. It is a matter of the deepest scientific interest to arrive at the truth, both as to the age of the solar system, the age of the earth as a body capable of supporting life, the successive orders and dates at which life actually appeared, and the manner and date of the appearence of the most highly organized form of life endowed with new capacities for developing reason and conscience in the form af Man. Those who wish to prove themselves worthy of their great good luck in having been born in a civilized country of the nineteenth century, and not in Palæolithic periods, will do well to show that curiosity, or appetite for knowledge, which mainly distinguishes the clever from the stupid and the civilized from the savage man, by studying the works of such writers as Lyell, Huxley, Tyndall, and Proctor, where they will find the questions here only briefly stated, developed at fuller length with the most accurate science and in the clearest and most attractive style. But for the moral, philosophical,

and religious bearings of these discoveries on the current of modern thought, there is such a wide margin that it becomes almost immaterial whether the shortest possible or longest possible periods should be ultimately established.

CHAPTER III.

MATTER.

WHAT is the material universe composed of? Ether, Matter, and Energy. Ether is not actually known to us by any test of which the senses can take cognizance, but is a sort of mathematical substance which we are compelled to assume in order to account for the phenomena of light and heat. Light, as we have seen, radiates in all directions from a luminous centre, travelling at the rate of 184,000 miles per second. Now what is light? It is a sensation produced on the brain by something which has been concentrated by the lens of the eye on the retina, and then transmitted along the optic nerve to the brain, where it sets certain molecules vibrating. What is the *something* which produces this effect? Is it a succession of minute particles, shot like rifle-bullets from the luminous body and impinging on the retina as on a target? Or is it a succession of tiny waves breaking on the retina as the waves of the sea break on the shore? Analogy suggests the latter, for in the case of the sister sense, Sound, we know as a fact that the sensation is produced on the brain by waves of air concentrated by the ear, and striking on the auditory nerve. But we have a more conclusive proof. If one of a series of particles shot out like bullets overtakes another, the force of impact of the two is increased; but if one wave overtakes another when the crest of the pursuing wave just coincides with the hollow of the wave before it the effect is neutralized, and if the two are of equal size it will be exactly neutralized and both waves will be effaced. In other words, two lights will make darkness. This, therefore, affords an infallible test. If two lights can make darkness, light is propagated, like sound, by waves. Now two lights do constantly make darkness, as is proved every day by numerous experiments. Therefore light is caused by waves.

But to have waves there must be a medium through which the waves are propagated. Without water you could not have ocean waves; without air you could not have sound-waves. Waves are in fact nothing but the successive forms assumed by a set of particles which, when forced from a position of rest, tend to return to that position, and oscillate about it. Place a cork on the surface of a still pond, and then throw in a stone; what follows? Waves are propagated, which seem to travel outwards in circles, but if you watch the cork, you will see that it does not really travel outwards, but simply rises and falls in the same place. This is equally true of waves of sound and waves of light. But the velocity with which the waves travel depends on the nature of the medium. In a dense medium of imperfect elasticity they travel slowly, in a rare and elastic medium quickly. Now the velocity of a sound-wave in air is about 1,100 feet a second, that of the light-wave about 184,000 miles a second, or about one million times greater. It is proved by mathematical calculation that, if the density of two media

are the same, their elasticities are in proportion to the squares of the velocities with which a wave travels. The elasticity of ether, therefore, would be a million million times greater than that of air, which, as we know, is measured by its power of resisting a pressure of about 15 lbs. to the square inch. But the ether must in fact be almost infinitely rare, as well as almost infinitely elastic, for it causes no perceptible retardation in the motions of the earth and planets. It must be almost infinitely rare also, because it permeates freely the interior of substances like glass and crystals, through which light-waves pass, showing that the atoms or ultimate particles of which these substances are composed, minute as they are, must be floating in ether like buoys floating on water or balloons in the air.

The dimensions of the light-waves which travel through this ether at the rate of 184,000 miles a second, can be accurately measured by strict mathematical calculations, depending mainly on the phenomena of interferences, *i.e.*, of the intervals required between successive waves for the crest of one to overtake the depression of another and thus make two lights produce darkness.

These calculations are much too intricate to admit of popular explanation, but they are as certain as those of the Nautical Almanac, based on the law of gravity, which enable ships to find their way across the pathless ocean, and they give the following results:

DIMENSIONS OF LIGHT-WAVES.

COLORS.	NUMBER OF WAVES IN ONE INCH.	NUMBER OF OSCILLATIONS IN ONE SECOND.
Red	39,000	477,000,000,000,000
Orange	42,000	506,000,000,000,000
Yellow	44,000	535,000,000,000,000
Green	47,000	575,000,000,000,000
Blue	51,000	622,000,000,000,000
Indigo	54,000	658,000,000,000,000
Violet	57,000	669,000,000,000,000

These are the colors whose vibrations affect the brain through the eye with the sensation of light, and which cause the sensation of white light when their different vibrations reach the eye simultaneously. But there are waves and vibrations on each side of these limits, which produce different effects, the longer waves with slower oscillations beyond the red, though no longer causing light causing heat, while the shorter and quicker waves beyond the violet cause chemical action, and are the most active agents in photography.

We must refer our readers to works treating specially of light for further details, and for an account of the vast variety of beautiful and interesting experiments with polarized light, colored rings, and otherwise, to which the theory of waves propagated through ether affords the key. For the present purpose it is sufficient to say that modern science compels us to assume, as the substratum of the material universe, such an ether extending everywhere, from the faintest star seen at a distance which requires thousands of years for its rays, travelling at the rate of 184,000 miles a second, to reach the earth, down to the infinitesimally small interspace between the atoms of the minutest matter. And throughout the whole of this enormous range law pre-

vails, ether vibrates and has always vibrated in the same definite manner, just as air vibrates by definite laws when the strings of a piano are struck by the hammers.

I pass now to the consideration of matter.

What is matter? In the most general sense it is that which has weight, or is subject to the law of gravity. The next analysis shows that it is something which can exist in the three forms of solid, liquid, or gas, according to the amount of heat. Diminish heat, and the particles approach closer and are linked together by mutual attraction, so as not to be readily parted; this is a solid. Increase the heat up to a certain point, and the particles recede until their mutual attractions in the interior of the mass neutralize one another, so that the particles can move freely, though still held together as a mass by the sum of all these attractions acting as if concentrated at the centre of gravity; this is the liquid state. Increase the heat still more, and the particles separate until they get beyond the sphere of their mutual attraction and tend to dart off into space, unless confined by some surface on which they exert pressure; this is a gas.

The most familiar instance of this is afforded by water, which, as we all know, exists in the three forms of ice, water, and vapor or steam, according to the dose of heat which has been incorporated with it.

Pursuing our inquiry further, the next great fact in regard to matter is that it is not all uniform. While most of the common forms with which we are conversant are made up of mixed materials, which can be taken to pieces and shown separately, there are, as at present ascertained, some seventy-one substances which defy chemical analysis to decompose them, and must therefore be taken as elementary substances. A great majority of these consist of substances existing in minute quantities, and hardly known outside the laboratories of chemists.

The world of matter, as known to the senses, is mainly composed of combinations, more or less complex, of a few elements. Thus, water is a compound of two simple gases, oxygen and hydrogen; air, of oxygen and nitrogen; the solid framework of the earth, mainly of combinations of oxygen with carbon, calcium, aluminum, silicon, and a few other bases; salt, of chlorine and sodium; the vegetable world directly and the animal world indirectly, mainly of complex combinations of oxygen, hydrogen, and nitrogen with carbon, and with smaller quantities of silicon, sulphur, potassium, sodium, and phosphorus. The ordinary metals, such as iron, gold, silver, copper, tin, lead, mercury, zinc, nearly complete the list of what may be called ordinary elements.

Now let us push our analysis a step further, How is matter made up of these elements? Up to and beyond the furthest point visible by aid of the microscope, matter is divisible. We can break a crystal into fragments, or divide a drop into drops, until they cease to be visible, though still retaining all the properties of the original substance. Can we carry on this process indefinitely, and is matter composed of something that can be divided and subdivided into fractional parts *ad infinitum?* The answer is, No, it consists of ultimate but still definite particles which cannot be further subdivided. How is this known? Because we find by experience that substances will only combine in certain definite proportions either of weight or measure. For instance, in forming water exactly eight grains by weight of oxygen combine with exactly one grain of hydrogen, and if there is any excess or fractional part of either gas, it remains over in its original form uncombined.

In like manner, matter in the form of gas always combines with other matter in the same form by volumes which bear a definite and very simple proportion to each other, and the compound formed bears a definite and very simple ratio to the sum of the volumes of the combining gases. Thus two volumes of hydrogen combine with one of oxygen to form two volumes of water in the state of vapor.

From these facts certain inferences can be drawn. In the first place it is clear that matter really does consist of minute particles, which do not touch and form a continuous solid but are separated by intervals which increase with increase of temperature. This is evident from the fact that we can pour a second or third gas into a space already occupied by a first one. Each gas occupies the enclosed space just as if there were no other gas present, and exerts its own proper pressure on the containing vessel, so that the total pressure on it is exactly the sum of the partial pressures. It is easy to see what this means. If a second regiment can be marched into a limited space of ground on which a first regiment is already drawn up, it is evident that the first regiment must be drawn up in loose order, *i.e.*, the soldier-units of which it is composed must stand so far apart that other soldier-units can find room between them without disturbing the formation. But the effect will be that the fire from the front will be increased, as for instance if a soldier of the second regiment, armed with a six-shooter repeating rifle, takes his stand between two soldiers of the first regiment armed with single-barrelled rifles, the effective fire will be increased in the ratio of 8 to 2. And this is precisely what is meant by the statement that the pressure of two gases in the same space is the sum of the separate pressures of each. It is clearly established that the pressure of a gas on a containing surface is caused by the bombarding to which it is subjected from the impacts of an almost infinite number of these almost infinitely small atoms, which, when let loose from the mutual attractions which hold them together in the solid and fluid state, dart about in all directions, colliding with one another and rebounding, like a set of little billiard-balls gone mad, and producing a certain average resultant of momentum outwards which is called pressure.

Another simile may help us to conceive how the indivisibility of atoms is inferred from the fact that they only combine in definite proportions. Suppose a number of gentlemen and ladies promenading promiscuously in a room. The band strikes up a waltz, and they at once proceed to group themselves in couples rotating with rhythmical motion in definite orbits. Clearly, if there are more ladies than gentlemen, some of them will be left without partners. So, if instead of a waltz it were a threesome reel, in which each gentleman led out two ladies, there must be exactly twice as many ladies as gentlemen for all to join in the dance. But if a gentleman could be cut up into fractional parts, and each fraction developed into a dancing gentleman, as primitive cells split up and produce fresh cells, it would not matter how many ladies there were, as each could be provided with a partner. Now this is strictly analogous to what occurs in chemical combination. Water is formed by each gentleman atom of oxygen taking out a lady atom of hydrogen in each hand, and the sets thus formed commence to dance threesome reels in definite time and measure, any surplus oxygen or hydrogen atoms being left out in the cold. Wonderful as it may appear, science enables us not only to say of these inconceivably

minute atoms that they have a real existence, but to count and weigh them. This fact has been accomplished by mathematical calculations based on laws which have been ascertained by a long series of experiments on the constitution of gases.

It is found that all substances, when in the form of gas, conform to three laws:

1. Their volume is inversely proportional to the pressure to which they are subjected.

2. Their volume is directly proportional to the temperature.

3. At the same pressure and temperature all gases have the same number of molecules in the same volume.

From the last law it is obvious that if equal volumes of two gases are of different weight, the cause must be that the molecules of the one are heavier than those of the other. This enables us to express the weight of the molecule of any other gas in some multiple of the unit afforded by the weight of the molecule of the lightest gas, which is hydrogen. Thus, the density of watery vapor being nine times that of hydrogen, we infer that the molecule of water weighs nine times as much as the molecule of hydrogen, and that of oxygen being eight times greater, we infer that the oxygen molecule is eight times heavier than that of hydrogen.

These weights are checked by the other law which has been stated, that chemical combination between different substances always takes place in certain definite proportions. Thus, whenever in a chemical process the original substances or the product are or might exist in the state of gas, it is always found that the definite proportions observed in the chemical process are either the proportions of the densities of the respective gases or some simple multiple of these proportions. Thus, the weight of hydrogen being 2, which combines with a weight of oxygen equal to 16 to form a weight of watery vapor equal to 18, the density of the latter is to that of hydrogen as 9 to 1, *i.e.*, as 18 to 2.

But to get to the bottom of the matter we must go a step further, and as we have decomposed substances into molecules, we must take the molecules themselves to pieces and see what they are made of. The molecule is the ultimate particle into which any substance can be divided retaining its own peculiar qualities. A molecule of water is as truly water as a drop or a tumblerful. But when chemical decomposition takes place, instead of the molecule of water we have molecules of two entirely different substances, oxygen and hydrogen. Nothing can well be more unlike than the product water and the component parts of which it is made up. Water is a fluid, oxygen a gas; water extinguishes fire, oxygen creates it. Water is a harmless drink, oxygen the base of the most corrosive acids. It is evident that the water-molecule is a composite, and that its qualities depend, not on the essential qualities of the atoms which have combined to make it, but on the manner of the combination, and the new modes of action into which these atoms have been forced. In his native war-paint oxygen is a furious savage; with a hydrogen atom in each hand he is a polished gentleman.

Our theory, therefore, leads beyond molecules to atoms, and we have to consider these particles of a still smaller order than molecules, as the ultimate indivisible units of matter of which we have been in search. And even these we must conceive of as corks, as it were, float-

ing in an ocean of ether, causing waves in it by their own proper movements, and agitated by all the successive waves which vibrate through this ether-ocean in the form of light and heat.

Working on these data, a variety of refined mathematical calculations made by Clausius, Clark Maxwell, Sir W. Thomson, and other eminent mathematicians, have given us approximate figures for the actual size, weight, and velocities of atoms and molecules. The results are truly marvellous. A millimetre is the one thousandth part of a metre, or roughly one twenty-fifth of an inch. The magnitudes with which we have to deal are all of an order where the standard of measurement is expressed by the millionth part of a millimetre. The volume of a molecule of air is only a small fraction of that of a cube whose side would be the millionth of a millimetre. A cubic centimetre, or say a cube whose side is between one-third and one-half of an inch, contains 21,000,000,000,000,000,000 molecules. The number of impacts received by each molecule of air during one second will be 4,700 millions. The distance traversed between each impact averages 95 millionths of a millimetre.

It may assist in forming some conception of these almost infinitely small magnitudes, to quote an illustration given by Sir W. Thomson as the result of mathematical calculation. Suppose a drop of water were magnified so as to appear of the size of the earth or with a diameter of 8,000 miles, the atoms of which it is composed, magnified on the same scale, would appear of a size intermediate between that of a rifle-bullet and of a cricket-ball.

These figures show that space and magnitude extend beyond the standards of ordinary human sense, such as miles, feet, and inches, as far downwards into the region of the infinitely small as they do upwards into that of the infinitely great.

And throughout the whole of this enormous range law prevails. The same law of gravity gives weight to molecules and atoms, makes an apple fall to the ground, and causes double stars to revolve round their centre of gravity in elliptic orbits. The law of polarity which converts iron-filings into small magnets under the influence of a permanent magnet or electric current, animates the smallest atom. Atoms arrange themselves into molecules, and molecules into crystals, very much as magnetized iron-filings arrange themselves into regular curves. And the great law seems to prevail universally throughout the material, as it does also throughout the moral world, that you cannot have a North without a South Pole, a positive without a negative, a right without a wrong; and that error consists mainly in what the poet calls "the falsehood of extremes"—that is, in allowing the attraction of one pole, or of one opinion, so to absorb us as to take no account of its opposite.

The universal prevalence of law has received wonderful confirmation of late years from the discovery made by the spectroscope that the sun, the planets, and the remotest stars are all composed of matter identical with that into which chemical analysis has resolved the constituent matter of the earth. This has been proved in the following way:

If a beam of light is admitted into a darkened room through a small hole or narrow slit, and a triangular piece of glass, called a prism, is interposed in its path, the image thrown on a screen is a rainbow-tinted streak, intersected by numerous fine dark lines, which is called a spectrum. If, instead of solar light, light from other luminous sources

is similarly treated, it is found that all elementary substances have their peculiar spectra. Light from solid or liquid substances gives a continuous spectrum, light from gases or glowing vapors gives a spectrum of bright lines separated from each other, but always in definite positions according to the nature of the substance. The next great step in the discovery was that these bright lines become dark lines when a light of greater intensity, coming from a solid nucleus, is transmitted through an atmosphere of such gases or vapors. We can thus photograph the spectrum of glowing hydrogen, sodium, iron, or other substances, and placing it below a photograph of a solar or stellar spectrum, see if any of the dark lines of the latter correspond with the bright lines of the former. If they do we may be certain that these substances actually exist in the sun or star. It is, in fact, just the same thing as if we had been able to bring down a jar full of the solar or stellar matter and analyze it in our laboratories.

It is difficult to convey any adequate description of these grand discoveries made by the new science of Spectroscopy without referring to special works on the subject; but it may be possible to give some general idea of the principles on which they are based.

Light consists of waves propagated through ether. These waves are started by the vibrations of the ultimate particles of matter, which, whether in the simplest form of atoms, in the more complex form of molecules, or in the still more complex form of compound molecules, have their own peculiar and distinct vibrations. These vibrations are increased, diminished, or otherwise modified by vibrations of heat and by the collisions which occur between the particles from their own proper motions. If we take the simplest case, that of matter in the form of a gas or vapor composed of single atoms, at a temperature just sufficient to become luminous and at a pressure small enough to keep the atoms widely apart, the vibrations are all of one sort, viz., that peculiar to the elementary substance to which they belong, and one set of waves only is propagated by them through the ether. The spectrum, therefore, of such a gas is a single line of light, in the definite position which is due to its refrangibility, *i.e.*, to the velocity of the particular wave of light which the particular vibration of those particular atoms is able to propagate.

When pressure is increased so that the particles are brought closer together, their vibrations made more energetic and their collisions more frequent, more waves, and waves of different qualities are started, and more lines appear in the spectrum and the lines widen out, until at length when the gas becomes very dense, some of the lines overlap and an approach is made towards a continuous spectrum. Finally, when the particles are brought so near together that the substance assumes a fluid or solid state, the number of wave-producing vibrations becomes so great that a complete system of different light-waves is propagated, and the lines of the spectrum are multiplied until they coalesce and form a continuous band of rainbow-tinted light. If the particles of the gas, instead of being single atoms, are more complex, as molecules or compound molecules, the vibrations are more complex and the different resulting light-waves more numerous, so that the lines in the spectrum are more numerous, and in some cases they coalesce so as to form shaded bands, or what are called fluted lines, instead of simple lines.

Moreover, whatever light-waves are originated by the vibrations

of the particles of a gas are absorbed into those vibrations and extinguished, if they originate from the vibrations of some more energetic particles of another substance outside of it, whose light-waves, travelling along the ether, pass through the gas, and are thus shown as dark lines in the spectrum of the other source of light.

We can now understand how the assertion is justified that we can analyze the composition of the sun and stars as certainly as if we had a jar full of their substance to analyze in our laboratory. The first glance at a spectrum tells us whether the luminous source is solid, fluid, or gaseous. If its spectrum is continuous it is solid or fluid; we know this for certain, but can tell nothing more. But if it consists of bright lines, we know that it comes direct from matter in the form of luminous gas, and knowing from experiments in the laboratory the exact colors and situations of the lines formed by the different elements of which earthly matter is composed, we can see whether the lines in the spectra of heavenly matter do or do not correspond with any of them. If bright lines correspond we are sure that the substances correspond, both as to their elementary atoms and their condition as glowing gas. If dark lines in the spectrum of the heavenly body correspond with bright lines in that of a known earthly substance, we are certain that the substances are the same and in the same state of gas, but that the solar or stellar spectrum proceeds from an intensely heated interior solid or fluid nucleus, whose waves have passed through an outer envelope or atmosphere of this gas.

Applying these principles, although the science is still in its infancy and many interesting discoveries remain to be made, this grand discovery has become an axiomatic fact—Matter is alike everywhere. The light of stars up to the extreme boundary of the visible universe, is composed mainly of glowing hydrogen, the same identical hydrogen as we get by decomposing water by a voltaic battery.

Of the 71 elementary substances of earthly matter enumerated by chemists, 9 may be considered as doubtful or existing only in excessively minute quantities. Of the remaining 62, 22 are known certainly to exist in the sun's atmosphere, 10 more can probably be traced there, and there are only 6 as to which, in the present state of our knowledge, there is negative evidence that they are not present. The elements whose presence is proved comprise many of those which are most common in the composition of the earth, as hydrogen, iron, lead, calcium, aluminium, magnesium, sodium, potassium, etc.; and if others, such as oxygen, carbon, and chlorine have not yet been found, good reasons may be assigned why they may not exist in a state likely to give recognizable spectrum-lines. The main fact is firmly established that matter is the same throughout all space, from the minutest atom to the remotest star.

Thus far we have been treating of matter only, and of force and motion but incidentally. These, however, are equally essential components of the phenomena of the universe. What is force? In the last analysis it is the unknown cause which we assume for motion, or the term in which we sum up whatever produces or tends to produce it. The idea of force, like so many other of our ideas, is taken from our own sensations. If we lift a weight or bend a bow, we are conscious of doing so by an effort. Something which we call will produces a motion in the molecules of the brain, which is transmitted by the nerves to the muscles, where it liberates a certain amount of

energy stored up by the chemical composition and decomposition of the atoms of food which we consume. This contracts the muscle, and the force of its contraction, transmitted by a system of pulleys and levers to the hand, lifts the weight. If we let go the weight it falls, and the force which lifted it reappears in the force with which it strikes the ground. If we do not let go the weight but place it on a support at the height to which we have raised it, it does not fall, no motion ensues, but the lifting force remains stored up in a tendency to motion, and can be made to reappear as motion at any time by withdrawing the support, when the weight will fall. It is evident, therefore, that force may exist in two forms, either as actually causing motion or as causing a tendency to motion.

In this generalized form it has been agreed to call it energy, as less liable to be obscured by the ordinary impressions attached to the word force, which are mainly derived from experiences of actual motion cognizable by the senses. We speak, therefore, of energy as of something which is the basis or *primum mobile* of all motion or tendency to motion, whether it be in the grosser forms of gravity and mechanical work, or in the subtler forms of moleculer and atomic motions causing the phenomena of heat, light, electricity, magnetism, and chemical action. This energy may exist either in the form of actual motion, when it is called energy of motion, or in that of tendency to motion, when it is called energy of position. Thus the bent bow has energy of position which, when the string is let go, is at once converted into energy of motion in the flight of the arrow.

Respecting this energy modern science has arrived at this grand generalization, that it is one and the same in all its different manifestations, and can neither be created nor destroyed, so that all these varied manifestations are mere transformations of the same primitive energy from one form to another. This is what is meant by the principle of the "Conservation of Energy."

It was arrived at in this way. Speaking roughly it has long been known that heat could generate mechanical power, as seen in the steam-engine; and conversely that mechanical power could generate heat, as is seen when a sailor, in a chill north-easter, claps his arms together on his breast to warm himself. But it was reserved for Dr. Joule to give this fact the scientific precision of a natural law, by actually measuring the amount of heat that was added to a given weight of water by a given expenditure of mechanical power, and conversely the amount of mechanical work that could be got from a given expenditure of heat.

A vast number of carefully-conducted experiments have led to the conclusion that if a kilogramme be allowed to fall through 424 metres and its motion be then suddenly stopped, sufficient heat will be generated to raise the temperature of one kilogramme of water by 1° Centigrade; and conversely this amount of heat would be sufficient to raise one kilogramme to a height of 424 metres.

If, therefore, we take as our unit of work that of raising one kilogramme one metre, and as our unit of heat that necessary to raise one kilogramme, of water 1° Centigrade, we may express the proportion of heat to work by saying that one unit of heat is equal to 424 units of work; or, as it is sometimes expressed, that the number 424 is the mechanical equivalent of heat.

But the question may be asked, what does this mean, how can

mechanical work be really transformed into heat or *vice versâ?* The answer is, the energy which was supplied by chemical action to the muscles of the man or horse, or to the water converted into steam by combustion of coal, which originated the mechanical work, was first transformed into its equivalent amount of mechanical energy of motion, and then, when that motion was arrested, was transformed into heat, which is simply the same energy transformed into increased molecular motion.

If we wish to carry our inquiry a step further back and ask where the original energy came from which has undergone these transformations, the answer must be, mainly from the sun. The sun's rays, acting on the chlorophyl or green matter of the plants of the coal era, tore asunder the atoms of carbon and oxygen which formed the carbonic acid in the atmosphere, and locked up a store of energy in the form of carbon in the coal which is burned to produce the steam. In like manner it stored up the energy in the form of carbon in the vegetable products which, either directly, or indirectly after having passed through the body of some animal, supplied the food, whose slow combustion in the man or horse supplied the energy which did the work.

But where did the energy come from which the sun has been pouring forth for countless ages in the form of light and heat, and of which our earth only intercepts the minutest portion? This is a mystery not yet completely solved, but one real cause we can see, which has certainly operated and perhaps been the only one, viz., the mechanical energy of the condensation by gravity of the atoms which originally formed the nebulous matter out of which the sun was made. If we ask how came the atoms into existence endowed with this marvellous energy, we have reached the furthest bounds of human knowledge, and can only reply in the words of the poet: "Behind the veil, behind the veil."

We can only form metaphysical conceptions, or I might rather call them the vaguest guesses. One is, that they were created and endowed with their elementary properties by an all-wise and all-powerful Creator. This is Theism.

Another, that thought is the only reality, and that all the phenomena of the universe are thoughts or ideas of one universal, all-pervading Mind. This is Pantheism.

Or again, we may frankly acknowledge that the real essence and origin of things are "behind the veil," and not knowable or even conceivable by any faculties with which the human mind is endowed in its present state of existence. This is Agnosticism.

There is one other conception, of which we may certainly say that it is not true—that is Atheism. No one with the least knowledge of science can maintain that it can ever be demonstrated that everything in the universe exists of itself and never had a Creator.

But these speculations lead us into the misty regions where, like Milton's devils, "we find no end in wandering mazes lost." Let us return to the solid ground of fact, on which alone the human mind can stand firmly, and like Antæus gather fresh vigor every time it touches it for further efforts to enlarge the boundaries of knowledge and extend the domain of Cosmos over Chaos.

The transformation of energy which we have seen to exist in the case of mechanical work and heat, is not confined to those two cases only, but is a universal law applicable to all actions and arrangements

of matter which involve motions of atoms, molecules, or masses, and therefore imply the existence of energy. In heat we have had an example of energy exerted in molecular motion and molecular separation. In chemical action we have energy exerted in the separation of atoms, severing them from old combinations and mutual attractions, and bringing them within the sphere of new ones. In electricity, and magnetism which is another form of electricity, we have energy of position which manifests itself in electrical separation, by which matter becomes charged with two opposite energies, positive and negative, which accumulate at separate poles, or on separate surfaces, with an amount of tension which may be reconverted into the original amount of energy of motion when the spark, passing between them, restores their electrical equilibrium. Of this we have an example in the ordinary electrical machine, where the original energy comes from the mechanical force which turns the handle, and is given back when the electric spark brings things back to their original state.

We have also energy of motion, when instead of electrical separation and tension we have a flow or current of electricity producing the effect of the electric spark in a slow, quiet, and continuous manner. Thus, in the voltaic battery, the free energy created by the difference of chemical action of an acid on plates of different metals, is transformed into a current which charges two poles with opposite electricities, and when the poles are brought together and the circuit is closed, flows through it in a continuous current. This current is an energetic agent which produces various effects. It deflects the magnetic needle, as is seen in the electric telegraph. It creates magnetism, as is seen when the poles of the battery are connected by a wire wrapped round and round a cylinder of soft iron, so as to make the current circulate at right angles to the axis formed by the cylinder. In fact, all magnetism may be consided as the summing up at the two opposite extremities or poles of an axis, of the effects of electric currents circulating round it; as, for instance, the earth is a great magnet because currents caused by the action of the sun circulate round it nearly parallel to the equator. Electric currents further show their energy by attracting and repelling one another, those flowing in the same direction attracting, and those in opposite directions repelling, the same effect showing itself in magnets, which are in substance collections of circular currents flowing from right to left or left to right according as they are positive or negative. Again, currents produce an effect by inducing currents in other bodies placed near them, very much as the vibrations of a tuning-fork induce vibrations and bring out a corresponding note from the strings of a piano or violin ready to sound it. When a coil of wire is connected with a battery and a current passes through it, if it is brought near to another isolated coil it induces a current in an opposite direction, which, when it recedes from it, is changed into a current in the same direction.

These principles are illustrated by the ordinary dynamo, by which the energy of mechanical work exerted in making magnets revolve in presence of currents, and by various devices accumulating electric energy, is made available either for doing other mechanical work, such as driving a wheel, or for doing molecular or atomic work by producing heat and light.

For another transformation of the energy of electric currents is into heat, light, or chemical action. If the two poles of a battery are

connected by a thin platinum wire it will be heated to redness in a few seconds, the friction or resistance to the currant in passing through the limited section of the thin wire producing great heat. If the wire is thicker heat will equally be produced, but more slowly.

If the poles of the battery are made of carbon, or some substance the particles of which remain solid during intense heat, when they are brought nearly together the current will be completed by an arc of intensely brilliant light, and the carbon will slowly burn away. This is the electric light so commonly used when great illuminating power is wanted.

Again, the electric current may employ its energy in effecting chemical action. If the poles of a battery, instead of being brought together, are plunged into a vessel of water, decomposition will begin. Oxygen will rise in small bubbles at the positive pole, and hydrogen at the negative. If these two gases are collected together in the same vessel, and an electric current, in the intense and momentary form of a spark, passed through them, they will combine with explosion into the exact amount of water which was decomposed in their formation.

Everywhere, therefore, we find the same law of universal application. Energy, like matter, cannot be created or destroyed, but only transformed. It is therefore, in one sense, eternal. But there is another point of view from which this has to be regarded.

Mechanical work, as we have seen, can always be converted into heat, and heat can, under certain conditions, be reconverted into mechanical work; but not under all conditions. The heat must pass from something at a higher temperature into something at a lower. If the condenser of a steam-engine were always at the same temperature as the boiler, we should get no work out of it. It is easy to understand how this is the case if we figure to ourselves a river running down into a lake. If the stream is dammed up at two different levels, each dam, as long as there is water in it, will turn a mill-wheel. But if all the water runs down into the lake and, owing to a dry season, there is no fresh supply, the wheels will stop and we can get no more work done. So with heat, if it all runs down to one uniform temperature it can no longer be made available to do work. In the case of the river, fresh water is supplied at the higher levels, by the sun's energy raising it by evaporation from the seas to the clouds, from which it is deposited as rain or snow. But in the case of heat there is no such self-restoring process, and the tendency is always towards its dissipation; or in other words, towards a more uniform distribution of heat throughout all existing matter. The process is very slow; the original fund of high-temperature heat is enormous, and as long as matter goes on condensing fresh supplies of heat are, so to speak, squeezed out of it.

Still there is a limit to condensation, while there is no limit to the tendency of heat to diffuse itself from hotter to colder matter until all temperatures are equalized. The energy is not destroyed; it is still there in the same average amount of total heat, though no longer differentiated into greater and lesser heats, and therefore no longer available for life, motion, or any other form of transformation. This seems to be the case with the moon, which, being so much smaller, has sooner equalized its heat with surrounding space, and is apparently a burnt-out and dried-up cinder without air or water. And this, as far as we see, must be the ultimate fate of all planets, suns, and solar systems. Fortunately the process is extremely slow, for even our small earth has

enjoyed air, water, sunshine, and all the present conditions necessary for life for the whole geological period, certainly from the Silurian epoch downwards, if not earlier, which cannot well be less than 100 millions of years, and may be much more. Still time, even if reckoned by hundreds of millions of years, is not eternity; and as, looking through the telescope at nebulæ which appear to be condensing about central nuclei, we can dimly discern a beginning, so, looking at the moon and reasoning from established principles as to the dissipation of heat, we can dimly discern an end. What we really can see is that throughout the whole of this enormous range of space and time law prevails; that, given the original atoms and energies with their original qualities, everything else follows in a regular and inevitable succession; and that the whole material universe is a clock, so perfectly constructed from the beginning as to require no outside interference during the time it has to run to keep it going with absolute correctness.

CHAPTER IV.

LIFE.

THE universe is divided into two worlds—the inorganic, or world of dead matter; and the organic, or world of life. What is life? In its essence it is a state of matter in which the particles are in a continued state of flux, and the individual existence depends, not on the same particles remaining in the same definite shape, but on the permanence of a definite mould or form through which fresh particles are continually entering, forming new combinations and passing away. It may assist in forming a conception of this if we imagine ourselves to be looking at a mountain the top of which is enveloped in a driving mist. The mountain is dead matter, the particles of which continue fixed in the rocks. But the cloud form which envelops it is a mould into which fresh particles of vapor are continually entering and becoming visible on the windward side, and passing away and disappearing to leeward. If we add to this the conception that the particles do not, as in the case of the cloud, simply enter in and pass away without change, but are digested, that is, undergo chemical changes by which they are partly assimilated and worked up into component parts of the mould, and partly thrown off in new combinations, we shall arrive at something which is not far off the ultimate idea of what constitutes living matter, in its simplest form of the protoplasm, or speck of jelly-like substance, which is shown to be the primitive basis or raw material of all the more complex forms both of vegetable and animal life. Digestion, therefore, is the primary attribute. A crystal grows from *without*, by taking on fresh particles and building them up in regular layers according to fixed laws, just as the pyramids of Egypt were built up by laying layer upon layer of squared stones upon surfaces formed of regular figures, and inclined to each other at determinate angles.

The living plant or animal grows from within by taking supplies of fresh matter into its inner laboratory, where it is worked up into a variety of complex products needed for the existence and reproduction of life. After supplying these, the residue is given back in various forms to the inorganic world, and the final residue of all is given back by death, which is the ultimate end of all life

The simplest form of life, in which it first emerges from the inorganic into the organic world, consists of protoplasm, or, as it has been called, the physical basis of life. Protoplasm is a colorless semi-fluid or jelly-like substance, which consists of albuminoid matter, or in other words, of a heterogeneous carbon-compound of very complex chemical composition. It exists in every living cell, and performs the functions of nutrition and reproduction, as well as of sensation and motion. In its simplest form, that of the microscopic monera or protista, the lowest of living beings, we find a homogeneous structureless piece of protoplasm, without any differentiation of parts. The monera are simple living globules of jelly, without even a nucleus or any sort of organ, and yet they perform all the essential functions of life without any different parts being told off for particular functions. Every particle or molecule is of the same chemical composition and a fac-simile of the whole body, as in the case of a crystal. They are, therefore, the first step from the inorganic into the organic world, and if spontaneous generation takes place anywhere, it is in the passage of the chemical elements from the simple and stable combinations of the former into the complex and plastic combinations of the latter.

These monera are found principally in the sea and in great masses at the bottom of deep oceans, where they form a sort of living slime first described by Huxley in 1868, and called Bathybius.

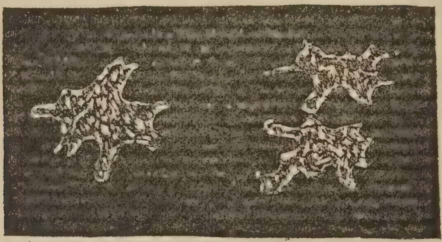
The next step upwards is to the cell in which the protoplasm is enclosed in a skin or membrane of modified protoplasm, and a nucleus, or denser spot, is developed in the enclosed mass. This is the primary element from which all the more complicated forms of life are built up. Each cell seems to have an independent life of its own, and a faculty of reproduction by splitting into fresh cells similar to itself, which multiply in geometrical progression, assimilating the elements of their substance from the inorganic world so rapidly as to provide the requisite raw material for higher structures.

The first organized living forms are extremely minute, and can only be recognized by powerful microscopes. A filtered infusion of hay, allowed to stand for two days, will swarm with living things, a number of which do not exceed $\frac{1}{40,000}$ of an inch in diameter. Minute as these animalcula are, they are thoroughly alive. They dart about and digest; the smallest speck of jelly-like substance shoots out branches or processes to seize food, and if these come in collision with other substances they withdraw them. They exist in countless myriads, and perform a very important part in the economy of nature. They are the scavengers of the universe, and remove the remains of living matter after death, which would otherwise accumulate until they choked up the earth. This they do by the process of putrefaction, which is due mainly to the multiplication of little rod-like creatures known as bacteria, which work up the once living, now dead, matter into fresh elements, again fitted to play their part in the inorganic and organic worlds.

One of the simplest of these forms is the amœba, which is nothing but a naked little lump of cell-matter, or plasma, containing a nucleus; and yet this little speck of jelly moves freely, it shoots out tongues or processes and gradually draws itself up to them with a sort of wave-like motion; it eats and grows, and in growing reproduces itself by contracting in the middle and splitting up into two independent amœbæ.

The germs of these various animalcula swarm in the air, and carry seeds of infection everywhere where they find a soil fitted to receive them; and thus assist the survival of the fittest in the struggle of life, by eliminating weak and unhealthy individuals and species. Thus when the potato, the vine, or the silk-worm has had its constitution enfeebled by prolonged artificial culture, there are germs always ready to revenge the violation of natural laws, and bring the survivors back to a more healthy condition. In like manner the germs of cholera, typhoid, and scarlet fever, enforce the observance of sanitary principles.

In this simple form the lowest forms of life are not yet sufficiently differentiated to enable us to distinguish clearly between animal and



AMŒBA. AMŒBA dividing into two.

vegetable, and they have been called by some naturalists Protista, while others designate them as Protozoa or Protophyta, according as they show more resemblance to one or the other form of life. But it is often so doubtful that in looking at the same organism through a microscope, Huxley was inclined to consider it as a plant, while Tyndall exclaimed that he could as soon believe that a sheep was a vegetable.

In the next stage upwards, however, life subdivides itself into two great kingdoms, that of the vegetable and of the animal world. Alike in their general definition as contrasted with inorganic matter, and in their common origin from an embryo cell, which divides and subdivides until cell-aggregates are formed, from which the living form is built up by a process of evolution, the plant differs from the animal in this: that the former feeds directly on inorganic matter, while the latter can only feed on it indirectly, after it has been manufactured by the plant into vegetable substance.

This is universally true, for if we dine on beef, we dine practically on the grass which the ox ate; that is, on the carbon, oxygen, hydrogen, and other simple elements which the grass, under the stimulus of light and sunshine, manufactured into complex compounds; and which the ox again, by a second process, manufactured from these compounds into others still more complex, and more easily assimilated by us in the process of digestion. But in no case can we dine, as the plant does, on the simple elements, and thrive on a diet of air and water, with a small admixture of nitrate of ammonia, and of phosphates, sulphates and chlorides, of a few primitive metals. Vegetable life, therefore, is the producer, and animal life the consumer, of the organic world.

Practically the plant derives most of its substance from the carbonic acid gas in the atmosphere, which green leaves under the stimulus of light and heat have the faculty of decomposing, and

abstract the carbon giving out the oxygen; while the animal, by a reverse process, burns up the compounds manufactured by the plant, principally out of this carbon, by the oxygen obtained from the air by the process of respiration, exhaling the surplus carbon in the form of carbonic acid gas.

The balancing effect of these two processes may be seen in any aquarium, where animals and vegetables live together in water which is kept pure, while it would become stagnant and poisonous in a few hours, if one of the two forms of life were removed. All that the animal requires therefore for its existence, materials with which to build up its frame and supply waste; heat with which to maintain its circulating fluids and other substances at a proper temperature; motive power or energy to enable it to move, feel, and in the case of man to think; are all proceeds of the slow combustion of materials derived from the vegetable world in the oxygen breathed from the air, just as the work done by a steam-engine is the product of a similar combustion, or chemical combination of the oxygen of the air with the coal shovelled into the fire-box. These distinctions, however, between animals and vegetables are not quite absolute, for, even in the more highly-organized forms of life, there is a border-land where some plants seem to perform the functions of animals, as in those which catch and consume flies and eat and digest pieces of raw meat.

Those who wish to pursue this interesting subject further will do well to read the Chapter on Living Matter in Huxley's "Physiography," where they will find it more fully explained, with the inimitable clearness which characterizes all the writings of an author who is at the same time one of the first scientific authorities and one of the greatest masters of English prose. But my present object is not to write a scientific treatise, but shortly to sum up the ascertained results of modern science, with a view to their bearings on modern thought; and from this point of view the immediate question is, how far law, which has been shown to prevail universally throughout space, time, and inorganic matter, can be shown to prevail equally throughout the world of life.

Up to a certain point this admits of positive proof. It is as certain that all individual life, from the most elementary protoplasm up to the highest organism Man, originates in a minute or embryo cell, as it is that oxygen and hydrogen combined in certain proportions make water. But if we try to go back one step further, behind the cell, we are stopped. In the inorganic world we can reason our way beyond the microscopic matter to the molecule, and from the molecule to the atom, and are only arrested when we come to the ultimate form of matter, and of energy, out of which the universe is built up. But, in the case of life, we are stopped two steps short of this, and cannot tell how the cell containing the germ of life is built up out of the simpler elements.

Many attempts have been made to bridge over this gulf, and show how life may originate in chemical compounds, but hitherto without success. Experiments have been made which, for a time, seemed to show that spontaneous generation was a scientific fact, *i.e.*, that the lowest forms of life, such as bacteria and amœba, really did originate in infusions containing no germs of life; but they have been met by counter experiments confirming Harvey's *dictum*, "Omne animal ex ovo," or all life proceeds from antecedent germs of life, and the verdict

of the best authorities, such as Pasteur, Tyndall, and Huxley is, that spontaneous generation has been "defeated along the whole line." This verdict is perhaps too unqualified, for it certainly appears that, on the assumption with which both sides started, that all organic life was destroyed by exposure to a heat of 212°, or the boiling-point of water, the advocates of spontaneous generation had the best of it, as low forms of life did appear in infusions which had been exposed to this heat, and then hermetically sealed, so as to prevent any germs from entering. But it was replied that, as a hard pea takes more boiling than a soft one, it might very well be that heat sufficient to destroy life in any moist organism of sufficient size to be seen by the microscope, might not destroy the germinating power of ultra-microscopic germs in a very dry state. And this position seems to have been confirmed by various experiments, showing that such ultra-microscopic germs really do exist, and are given forth in the last life stage of the bacteria which cause putrefaction; and that if they are absent or destroyed by repeated applications of heat, infusions will keep sweet for ever in optically pure air.

Above all, the germ theory has received confirmation from the brilliant practical results to which it has led in the hands of Pasteur, enabling him to detect, and to a great extent eradicate, the causes which had led to the oidium of the vine and the pebrine of the silk-worm, thereby saving losses of millions to the industries of France. The germ theory has also led to important results in medical science, and is pointing towards the possibility of combating the most fatal diseases by processes analogous to that by which vaccination has almost freed the human race from the scourge of small-pox.

On the whole, therefore, we must be content to accept a verdict of "Not proven" in the case of spontaneous generation, and admit that as regards the first origin of life, science fails us, and there is at present no known law that will account for it.

Should spontaneous generation ever be proved to be a fact, it will doubtless be in creating living protoplasm from inorganic elements at its earliest stage, before it has been differentiated even into the primitive form of a nucleated cell or that of an amœba. This is what the doctrine of evolution would lead us to expect, for it would be in contradiction to it to suppose that the starting-point could be interpolated at any stage subsequent to the lowest. It may be also that this step could only be made under conditions of heat, pressure, and otherwise, which existed in the earlier stage of the earth's existence, but have long since passed away.

This, however, is only a small part of the difficulty we have to encounter in reducing life to law.

These primeval embyro cells, like as they are in appearance, contain within them the germs of an almost infinite diversity of evolutions, each running its separate course distinct from the others. The world of life is not one and uniform, but consists of a vast variety of different species, from the speck of protoplasm up to the forest tree, and from the humble amœba up to man, each one, at any rate within long intervals of time, breeding true and keeping to its own separate and peculiar path along the line of evolution.

The first germ, or nucleated cell, of a bacteria develops into other bacteria and nothing else, that of a coral into corals, of an oak into oaks, of an elephant into elephants, of a man into man. In the latter

case we can trace the embryo in its various stages of growth through forms having a certain analogy to those of the fish, the reptile, and the lower mammals, until it finally takes that of the human infant. But we have no experience of a fish, a frog, or a dog, being ever born of human parents, or of any of the lower animals ever producing anything resembling a man.

How can this be explained? Naturally the first attempt at explanation was by miracle. At a time when everything was explained by miracle, when all unusual occurrences were attributed to supernatural agency, and men lived in an atmosphere of providential interferences, witchcraft, magic, and all sorts of divine and diabolic agencies, nothing seemed easier than to say the beasts of the field, the birds of the air, and the fishes of the sea are all distinct after their kind, because God created them so.

But as the supernatural faded away and disappeared in other departments where it had so long reigned supreme, and science began to classify, arrange, and accumulate facts as they really are, it became more and more difficult, or rather impossible, to accept this simple explanation. The very first step destroyed the validity of all the traditional myths which described the origin of life from one simultaneous act of creation at a single centre. The earth is divided into separate zoölogical provinces, each with its own peculiar animal and vegetable world. The kangaroo, for instance, is found in Australia and there only. By no possibility could the aboriginal kangaroo have jumped at one bound from Mount Ararat to Australia, leaving no trace of his passage in any intermediate district. This isolation of life in separate provinces applies so rigidly, that we may sum it up by saying generally that there are no forms of life common to two provinces unless where migration is possible, or has been possible in past geological periods.

In islands at a distance from continents, we find common forms of marine life, for the sea affords a means of communication; and often common forms of bird, insect, and vegetable life, where they may have been wafted by the winds; but forms which neither in the adult or germ state could swim or fly, or be transported by something which did swim or fly, are invariably wanting. New Zealand affords a most conspicuous instance of this. Here is a large country with a soil and climate exceptionally well adapted to support a large amount of animal life of the higher orders, and yet it had absolutely no land animals before they were introduced by man. If special creations took place to replenish the earth as soon as any portion of its surface becomes fit to sustain it, why were there no animals in New Zealand? Or, in the Andaman Islands, in the Gulf of Bengal, which are as large as Ireland, covered with luxuriant vegetation, and within 300 miles of the coast of Asia, where similar jungles swarm with elephants, tigers, deer, and all the varied forms of mammalian life, there are no mammalia except a pigmy black savage and a pigmy black pig, the latter probably introduced by man.

The sharpness of the division between zoölogical provinces is well illustrated by that drawn by the Straits of Lombok, where a channel, not twenty miles wide, separates the fauna of Asia and Australia so completely that there are no species of land animals, and only a few of birds and insects, common to the two sides of a channel not so wide as the Straits of Dover.

There is no possibility of accounting for this, except by supposing

that the deep water fissure of the Strait of Lombok has existed from remote geological periods, and barred the migration southwards of those Asiatic animals, which, as long as they found dry land, migrated northwards and westwards till they were stopped by the Polar and Atlantic Oceans. This difficulty of requiring special creations for separate provinces is enormously enhanced if we look beyond the existing condition of things, and trace back the geological record. We must suppose separate creations for all the separate provinces of the separate successive formations from the Silurian upward. And the more we investigate the conditions of life either under existing circumstances or in those of past geological epochs, the more enormously are we driven to multiply the number of separate creations which would be necessary to account for the diversity of species. We find life shading off into an indefinite variety of almost imperceptible gradations from the highest organism, man, to the lowest, or speck of protoplasm, and we can draw no hard and fast line and say, up to this point life originated in law, and beyond it we must have recourse to miracle. Either all life or none is a product of evolution acting by defined law, and the affirmation of law is the negation of miracle.

Every day brings us an account of some new discovery bringing forms of life nearer together and bridging over intervals thought to be impassable. The discovery of plants living on insects, and which devour and digest pieces of raw meat, has added to the difficulty which has been long felt, in the humbler forms of life, of drawing any clear line of demarcation between the animal and vegetable worlds.

Microscopic research brings to light fresh facts confounding our fixed ideas as to the permanence of particular modes of reproducing life, and showing that the same organism may run through various metamorphoses in the course of its life-cycle, during some of which it may be sexual and in others asexual, *i.e.*, it may reproduce itself alternately by the co-operation of two beings of opposite sex, and by fissure or budding from one being only which is of no sex.

These, and a multitude of other similar facts, complicate enormously the problems of life and its developments, whether we attempt to solve it by calling in aid a perpetual series of innumerable miraculous interpositions, or by appealing to ordinary known laws of Nature.

Is the latter solution possible, and can the organic world be reduced, as the inorganic world has been with all its mysteries and infinities of space, time, and matter, from chaos into cosmos, and shown to depend on permanent and harmonious laws? Is the world of life, like that of matter, a clock, so perfectly constructed from the first that it goes without winding up or regulating? or is it a clock which would never have started going, or having started would soon cease to go if the hand of the watchmaker were not constantly interfering with it? This is the question which the celebrated Darwinian theory attempts to answer, of which I now proceed to give a short general outline.

The varieties among domestic animals are obvious to every one. The race-horse is a very different creature from the dray-horse; the short-horned ox from the Guernsey cow; the greyhound from the Skye terrier. How has this come to pass? Evidently by man's intervention, causing long-continued selection in breeding for certain objects. The English race-horse is the product of mating animals distinguished for speed for some fifteen or twenty generations. The greyhound is a similar dog-product by breeding for a longer period

with the same object; as the Skye terrier is of selection in order to get a dog which can follow a fox into a cairn of rocks and fight him when he gets there. In all these cases it is evident that the final result was not attained at once, but by taking advantage of small accidental variations and accumulating them from one generation to another by the principle of heredity, which make offspring reproduce the qualities of their parents.

The most precise and scientific experiments on this power of integrating, or summing up, a progressive series of differentials, or minute differences, between successive generations, are those conducted by Darwin on pigeons. He has shown conclusively that all the races of domestic pigeons, of which there are two or three hundred, are derived from one common ancestor, the wild or blue rock pigeon, and that the pigeon-fancier can always obtain fresh varieties in a few generations by careful interbreeding. Of the existing varieties many now differ widely from one another, both in size, appearance, and even in anatomical structure, so that if they were now discovered for the first time in a fossil state or in a new country, they would assuredly be classed by naturalists as separate species.

This is the work of man; is there anything similar to it going on in Nature? Yes, says Darwin, there is a tendency in all life, and especially in the lower forms of life, to reproduce itself vastly quicker than the supply of food and the existence of other life can allow, and the balance of existence is only preserved by the wholesale waste of individuals in what may be called the "struggle for life." In this struggle, which goes on incessantly and on the largest scale, the slightest advantage must tell in the long run, and on the average, in selecting the few who are to survive, and such slight advantages must tend to accumulate from one generation to another under the law of heredity. The cumulative power of selection exercised by man in the breeding of races is therefore necessarily exercised in Nature by the struggle for life, and in the course of time, by the cumulation of advantages originally slight, small and fluctuating variations are hardened into large and permanent ones, and new species are formed.

Darwin illustrates this principle of the "struggle for life" with a vast variety of instances, showing how the balance of animal and vegetable life may be preserved or destroyed in the most unexpected manner. For instance, the fertilization of red clover is effected by humble-bees, and depends on their number; the number of bees in a given district depends mainly on the number of field-mice which destroy their combs and nests; the number of mice depends on the number of cats; and thus the presence or absence of a carnivorous animal may decide the question whether a particular sort of flora shall prevail over others or be extirpated.

The countless profusion with which any one species, unchecked by its natural foes, may multiply in a given district, is illustrated by the potato disease, which in a few days invades whole countries; and by the rabbit plague in Australia and New Zealand, where, in less than twenty years, the descendants of a few imported pairs have rendered whole provinces useless for sheep pasture, and stoats are now being imported to restore the balance of life. The tendency in species to produce varieties which by selection may become exaggerated and fixed, is illustrated by the case of the Ancon herd of sheep. A ram lamb was born in Massachusetts in 1791, which had short crooked legs

and a long back like a turnspit dog. Being unable to jump over fences like the ordinary sheep, it was thought to possess certain advantages to the farmer, and the breed was established by artificial selection in pairing this ram with its descendants who possessed the same peculiarities. The introduction of the Merino superseded the Ancon by giving a tame sheep not given to jump fences, with a better fleece, and so the breed was not continued, but it is certain that it might have been established as a permanent variety differing from the ordinary sheep as much as the turnspit or Skye terrier differs from the ordinary dog. The tendency of Nature to variation is apparent in the fact that of the many hundred millions of human beings living on the earth, no two are precisely alike, and varieties often appear, as in giants and dwarfs, six-fingered or toed children, hairy and other families, which might doubtless be fixed and perpetuated by artificial or natural selection, until they became strongly marked and permanent.

It is evident that if the theory of development is true it excludes the old theory of design, or rather, it thrusts it back in the organic, as it has been thrust back in the inorganic world, to the first atoms or origins which were made so perfect as to carry within them all subsequent phenomena by necessary evolution. Design and development lead to the same result, that of producing organs adapted for the work they have to do, but they lead to it in totally different ways. Development works from the less to the more perfect, and from the simpler to the more complicated, by incessant changes, small in themselves but constantly accumulating in the required direction. Design supposes that organisms were created specially on a predetermined plan, very much as the sewing-machine or self-binding reaper were constructed by their inventors.

Until quite recently all adaptations of means to ends were considered as evidences of design. A series of treatises was published some thirty years ago, for prizes left by a late Duke of Bridgewater, to illustrate this theme, among which one by Sir Charles Bell on the Hand attracted a good deal of attention. It was shown what an admirable machine the human hand is for the various purposes for which it is used, and the inference was drawn that it must have been created so by a designer who adapted means to ends in much the same way as is done by a human inventor. But more complete knowledge has dispelled this idea, and shown that the design, if there be any, must be placed very much farther back, and is in fact involved in the primitive germ from which all vertebrate life certainly, and probably all life, animal or vegetable, have been slowly developed.

The human hand is in effect the last stage of a development of the vertebrate type, or type of life in which a series of jointed vertebræ form a backbone, which protects a spinal cord containing the nervous centres, gives points of attachment for the muscles, and forms an axis of support for the looser tissues. Certain of these vertebræ throw out bony spines or rays; at first, by a sort of simple process of vegetable growth, which formed the fins of fishes; then some of these rays dropped off and others coalesced into more complex forms, which made the rudimentary limbs of reptiles; and finally, the continued process of development fashioned them into the more perfect limbs of birds and mammals. In this last stage a vast variety of combinations was developed. Sometimes the bones of the extremities spread out, so as to form long fingers sugporting the feathered wings of birds and the

membraneous wings of bats; sometimes they coalesced into the solid limbs supporting the bodies of large animals, as in the case of the horse; and finally, at the end of the series, they formed that marvellous instrument, the hand, as it appears in the allied genera of monkeys, apes, and man.

Any theory of secondary design and special miraculous creation must evidently account for all the intermediate forms as well as for the final result. We must suppose not one but many thousands of special creations, at a vast variety of places and over a vast extent of time; we must take into account not the successes only, but the failures, where organs appear in a rudimentary form which are perfectly useless, or in some cases even injurious, to the creature in which they are found. For instance, in the case of the so-called wingless birds, like the dodo of the Mauritius, and the apteryx of New Zealand, which are found in oceanic islands, evolution accounts readily for the atrophy or want of development of organs which were not wanted where the birds had no natural enemies and found their food on the ground; but why should they have been created with rudimentary wings, useless while they remained isolated, and insufficient to prevent their extermination as soon as man, or any other natural enemy, reached the islands where they had lived secure?

If we are to adopt the theory of design and special creation, we must be prepared to take Burns' poetical fancy as a scientific truth, and believe that Nature had to try its "prentice hand," and grope its way through repeated trials and failures from the less to the more perfect. Again, the theory of special creation must account not only for the higher organs and forms of life, but for the lower forms also. Are the bacteria, amœbæ, and other forms of life which the microscope shows in a drop of water all instances of a miraculous creation? And still more hard to believe, is this the origin of the whole parasitic world of life which is attached to and infests each its own peculiar form of higher life? Is the human tape-worm a product of design, or that wonderful parasite the trichinia, which oscillates between man and the pig, being capable of being born only in the muscles of the one, and of living only in the intestines of the other?

These are the sort of difficulties which have led the scientific world, I may say universally, to abandon the idea of separate special creations, and to substitute for it that which has been proved to be true of the whole inorganic world of stars, suns, planets, and all forms of matter; the idea of an original creation (whatever creation may mean and behind which we cannot go) of ultimate atoms or germs, so perfect that they carried within them all the phenomena of the universe by a necessary process of evolution.

This is the idea to which the Darwinian theory leads up, by showing natural causes in operation which must inevitably tend to cause and to accumulate slight varieties, until they become large in amount and permanent, thus developing new races within old species, new species within old families, new families within old types, and new and complex types from old and simple ones.

The theory is up to a certain point undoubtedly true, and beyond that point in the highest degree probable, but scientific caution obliges us to add that it is still to a considerable extent a "theory," and not a "law." That is, it is not like the law of gravity, a demonstrated certainty throughout the whole universe, but a provisional law

which accounts for a great number of undoubted facts, and supplies a framework into which all other similar facts, as at present ascertained, appear to fit with a probability not approached by any other theory, and which is enhanced by every fresh discovery made, and by the analogy of what we know to be the laws which regulate the whole inorganic world.

To enable us to talk of the "Darwinian law," and not of the "Darwinian theory," we require two demonstrations:

1. That living matter really can originate from inorganic matter.
2. That new species really can be formed from previously existing species.

As regards the first, we have seen that the efforts of science have hitherto failed to produce an instance of spontaneous generation, and all we can say is that it is probable that such instances have occurred in earlier ages of our planet, under conditions of light, heat, chemical action, and electricity, different from anything we can now reproduce in our laboratories. This, however, falls short of demonstration, and for the present we must be content to leave the orgin of life as one of the mysteries not yet brought within the domain of law.

As regards the second point, we are further advanced towards the possibility of proof. But here also we are met by two difficulties. If we appeal to historical evidence, we are met by the fact that a much greater time than is embraced by any historical record is almost necessarily required for the dying out of any old species and introduction of any new one, by natural selection. And if we appeal to fossil remains we are met by the imperfection of the geological record. As to this, it must be remembered that only a very small portion of the earth's surface has been explored, and of this a very small portion consists of ancient land surfaces or fresh water formations, where alone we can expect to meet with traces of the higher forms of animal life. And even these have been so imperfectly explored, that where we now meet with thousands and tens of thousands of undoubted human remains lying almost under our feet, it is only within the last thirty years that their existence has ever been suspected. Cuvier, the greatest authority of the last generation, laid it down as an incontrovertible fact that neither men nor monkeys had existed in the fossil state, or in anything more ancient than the most superficial and recent deposits. We have now at least twenty specimens of fossil monkeys from one locality alone of the Miocene period, that of Pikermi, near Athens, and many thousands of human remains, at least into the Quaternary period and contemporary with extinct animals, if not earlier. We must be content, therefore, with approximate solutions pointing up to but not absolutely demonstrating the truth.

What is a species? Speaking generally it is an assemblage of individuals who maintain a separate family type by breeding freely among themselves, and refusing to breed with other species. There can be no doubt that this represents what, at the first view and for a limited range of time, is in accordance with actual facts. The animal and vegetable worlds are practically mapped out into distinct species, and do not present the mass of confusion which would result from indiscriminate cross-breeding. It is clear also that this state of things has lasted for a considerable time, for the paintings on Egyptian tombs and monuments carry us back more than 4,000 years, and show us the most strongly marked varieties of the human race, such as the

Semitic, the Egyptian, and the Negro, existing just as they do at the present day. They show us also such extreme varieties of the dog species as the greyhound and the turnspit, then in existence; and the skeletons of animals such as the ox, cat, and crocodile, which have been preserved as mummies, show no appreciable difference from those of their modern descendants.

When we come to look closely, however, into the matter, our faith in this absolute rule of the entire independence of species is greatly modified. In the lower grades of life we see everywhere species shading off into one another by insensible gradations, and every extension of our knowledge, both of the existing animal, vegetable, and microscopic worlds, and of those of past geological periods, multiplies instances of intermediate forms, differing from one another far less than do many of the individual varieties of recognized species. In the case of sponges, for instance, the latest conclusion of scientific research is this: that if you rely on minute distinctions as constituting distinct species, there are at least 300 species of one family of sponges, while if you disregard slight differences, which graduate into one another, and are found partly in one and partly in another variety, you must designate them all as forming only one species. Even in higher grades, as species are multiplied, it becomes more and more difficult to say where one ends and the other begins. Take the familiar instance of the grouse and ptarmigan. The red grouse is believed to be peculiar to the British Islands, while the ptarmigan is a very widely spread inhabitant of Arctic regions and high mountains. Which is more probable—that the grouse was specially created in the British Islands, apparently for the final cause of bringing sessions of Parliament to wind up business in August, or that, as the rigor of the Glacial period abated, and heather began to grow, certain ptarmigan by degrees modified their habits and took to feeding on heather tops instead of lichens, and by so doing gradually became larger birds and assumed the color best adapted for protection in their new habitation? In point of fact, grouse showing traces of this descent in smaller size and much whiter plumage are still to be met with. It would be easy to multiply instances, but this consideration seems conclusive.

If we reject the Darwinian theory and adopt that of independent species descended from a specially created ancestor or pair of ancestors, we are driven by each discovery of intermediate or slightly modified forms, into the assumption of more and more special acts of creation, until the number breaks down under its own weight, and belief becomes impossible.

For instance, in the Madeira Islands alone, 134 species of air-breathing land-snails have been discovered by naturalists, of which twenty-one only are found in Africa or Europe, and 113 are peculiar to this small group of islands, where they are mostly confined to narrow districts and single valleys. Are we to suppose that each of these 113 species was separately created? Is it not almost certain that they are the modified descendents of the twenty-one species which had found their way there in a former geological period, when Madeira was united to Africa and Spain?

There remains only the argument from the fertility of species *inter se*, and their refusal to breed with other species. This also, when closely examined, appears to be a *primâ facie* deduction, rather than an absolute law. Different species do, in fact, often breed together,

as is seen in the familiar instance of the horse and ass. It is true that in this case the mule is sterile and no new race is established. But this rule is not universal, and quite recently one new hybrid race, that of the leporine, or hare-rabbit, has been created, which is perfectly fertile. The progeny of dog and wolf has also been proved to be perfectly fertile during the four generations for which the experiment was continued. In the case of cultivated plants and domestic animals, there can be little doubt that new races, which breed true and are perfectly fertile, have been created within recent times from distinct wild species. The Esquimaux dog is so like the Arctic wolf that there can be little doubt he is either a direct descendant, or that both are descendants from a common stock. The same is true of the jackal and some breeds of dogs in the East and Africa, and other races of dogs are closely akin to foxes. But all dogs breed freely together, and can with difficulty be mated with the wild species which they so closely resemble. The modern Swiss cattle are pronounced by Rutimeyer to show undoubted marks of descent from three distinct species of fossil oxen, the *Bos primigenius*, *Bos longifrons*, and *Bos frontosus*.

There is now in the Zoölogical Gardens in Regent's Park a hybrid cow, whose sire was an American bison and its mother a hybrid between a zebu and a gayal. This animal is perfectly fertile, and has bred again to the bison; but what is singular is, that this hybrid resembles much more an ordinary domestic English cow than it does any of its progenitors. It is totally unlike the bison, both in appearance and disposition, and, except in having a projecting ridge over the withers, it might be mistaken for a coarse, bony, common cow. If a hybrid bull had been born of the same type, and mated with this hybrid cow, there is little doubt that a new race might have been established, extremely different from its ancestors.

In fact, nearly all the domesticated animals have the essential characters of new races. We cannot point to wild progenitors existing in any part of the world from which they are descended, and when they run wild they do not revert to any common ancestral form.

In the vegetable world instances of fertile hybrids are still more abundant, and the introduction and establishment of new varieties is a matter of every-day occurrence.

Now, whatever artificial selection can do in a short time, natural selection can certainly do in a longer time, and nothing short of absolute proof of the impossibility of species coming into existence by natural laws should induce us to fall back on the supernatural theory, with all its enormous difficulties of an innumerable multitude of special creations, most of them obviously imperfect and tentative—or rather, useless and senseless on any supposition except that of a necessary and progressive evolution. In fact, if it were not for its bearing on the nature and origin of man, few would be found to maintain the theory of miraculous creations, or to doubt that the world of life is regulated by fixed laws as well as the world of matter. But whatever touches man touches us closely, and brings into play a host of cherished aspirations and beliefs, which are too powerful to be displaced readily by calm, scientific reasoning. Shall man, who, we are told, was created in God's image and only "a little lower than the angels," be degraded into relationship with the brutes, and shown to be only the last development of an animal type which, in the case of apes and monkeys, approaches singularly near to him in physical structure? Are the

saints and heroes whom we revere, and the beautiful women whom we admire, descended, not from an all-glorious Adam and all-lovely Eve, as portrayed in Milton's "Paradise Lost," but from Palæolithic savages, more rude and bestial than the lowest tribe of Bushmen or Australians? Is the account of man's creation and fall in the Hebrew Scriptures as pure a myth as that of Noah's ark, or of Deucalion and Pyrrha?

The only answer to these questions is that truth is truth, and fact is fact, and that it is always better to act and to believe in conformity with truth and fact, than to indulge in illusions. There are many things in Nature which jar on our feelings and seem harsh and disagreeable, but yet are hard facts, which we have to recognize and make the best of. Childhood does not pass into manhood without exchanging much that is innocent and attractive for much that is stern and prosaic. Death, with its prodigal waste of immature life, its sudden extinction of mature life in the plenitude of its powers, its heart-rending separations from loved objects, is a most disagreeable fact. But it would not improve matters to keep grown-up lads in nurseries for fear of their meeting with accidents, or becoming hardened by contact with the world. Progress, not happiness, is the law of the world; and to improve himself and others by constant struggles upwards is the true destiny of man.

In working out this destiny the fearless recognition of truth is essential. Facts are the spokes of the ladder by which we climb from earth to heaven, and any individual, nation, or religion, which, from laziness or prejudice, refuses to recognize fresh facts, has ceased to climb and will end by falling asleep and dropping to a lower level.

"Prove everything, hold fast that which is true," is the maxim which has raised mankind from savagery to civilization, and which we must be prepared to act upon at all hazards and at all sacrifices, if we wish to retain that civilization unimpaired and to extend it further.

CHAPTER V.

ANTIQUITY OF MAN.

GREAT as the effect has been of the wonderful discoveries of modern science of which I have attempted to give a general view in the preceding chapters, there remains one which has had the greatest effect of all in changing the whole current of moden thought, viz., the discovery of the enormous antiquity of man upon earth, and his slow progress upwards from the rudest savagery to intelligence, morality, and civilization. It is needless to point out in what flagrant and direct opposition this stands to the theory that man is of recent miraculous creation, and that he was originally endowed with a glorious nature and high faculties, which were partially forfeited by an act of disobedience. It is important, therefore, to understand clearly the evidence upon which a conclusion rests, so startling and unexpected as that which traces the origin of man back into the remote periods of geological time.

It had been long known that a stone period preceded the use of metals. Flint arrow-heads, stone axes, knives, and chisels, rude

pottery, and other human remains lie scattered almost everywhere, on or near the existing surface, and are found in the sepulchral mounds and monuments which abound in all countries until they are destroyed by the progress of agriculture. These are certainly ancient, for their origin was so completely forgotten that the stone hatchets or celts (from the Latin *celtis*, or chisel) were universally believed to be thunderbolts which had fallen from heaven. But there was no proof that they were very ancient, they were always found at or near the present surface, and if animal remains were associated with them, they were those of the dog, ox, sheep, red deer, and other wild and domestic species now found in the same district. Historical record was not supposed to extend beyond the 4,000 or 5,000 years assigned to it by Bible chronology, and it was thought that this might be sufficient to account for all the changes which had occurred since man first became an inhabitant of the earth. Above all, the negative evidence was relied on, that geologists had explored far and wide, and although they had found fossil remains which enabled them to restore the characteristic fauna of so many different formations, they had found no trace of man or his works anywhere below the present surface. This seemed so conclusive that Cuvier, the greatest authority of the day, pronounced an emphatic verdict that man had not existed contemporaneously with any of the extinct animals, and probably not for more than 5,000 or 6,000 years. Here, then, appeared to be an edifice based on scientific fact, in which geologists and theologians could dwell together comfortably, and the weight of their united authority was sufficient to silence all objections, and ignore or explain away the instances which occasionally cropped up, of human remains found in situations implying greater antiquity.

Suddenly, I may almost say in a single day, this edifice collapsed like a house of cards, and the fact became apparent that the duration of human life on the earth must be measured by periods of tens, if not of hundreds of thousands of years.

It happened thus: A retired French physician, Monsieur Boucher de Perthes, residing at Abbeville, in the valley of the Somme, had a hobby for antiquarianism as decided as that of Monkbarns himself. Abbeville afforded him a capital collecting-ground for the indulgence of his tastes, as the sluggish Somme flows through a series of peat mosses, which are extensively worked for fuel, and afford many remains of the Gallo-Roman and pre-Roman or Celtic period. Higher up, on the slopes of the low hills which bound the wide valley, are numerous beds of gravel, sand, and brick-earth, which are also extensively worked for road and building materials. In these pits remains of the mammoth, rhinoceros, and other extinct animals are frequently found, and the workmen had noticed occasionally certain curiously-shaped flints, to which they gave the name of "langues du chat," or cats' tongues. Some of these were taken to Monsieur Boucher de Perthes as curiosities for his museum, and he at once recognized them as showing marks of human workmanship. This put him on the trace, and in the year 1841 he himself discovered, *in situ*, in a seam of sand containing remains of the mammoth, a flint rudely but unmistakably fashioned by human hands into a cutting instrument. During the next few years a large quantity of gravel was removed to form the Champ de Mars at Abbeville, and many of these celts or hatchets were found. In 1847, M. Boucher de Perthes published his "Antiquités Celtiques et Antédilu-

viennes," giving an account of these discoveries, but no one would listen to him. The united authority of theologians and geologists opposed an infallible veto on the reception of such ideas, and it must be admitted that M. Boucher de Perthes himself did his best to discredit his own discoveries by associating them with visionary speculations about successive deluges and creations of pre-Adamite men. At length Dr Falconer, the well-known palæontologist, who had brought to light so many wonderful fossil remains from the Sewalik hills in India, happened to be passing through Abbeville and visited M. Boucher de Perthes' collection. He was so much struck by what he saw that on arriving in London he spoke to Mr. Prestwich, the first living authority on the tertiary and quaternary strata, and Mr. Evans, whose authority was

FLINT HÂCHE,
From Moulin Quignon, Abbeville.
(Half the actual size.)

FLINT HÂCHE,
From St. Acheul, Valley of the Somme.
(Half the actual size.)

(From Lubbock's "Prehistoric Times.")

equally great on everything relating to the stone implements found in such numbers in the more recent or Neolithic period. He urged them to go to Abbeville and examine for themselves whether there was anything in these alleged discoveries. They did so, and the result was that on their return to England Mr. Prestwich read a paper to the Royal Society on the 19th May, 1859, which conclusively and forever established the fact that flint implements of unmistakable human workmanship had been found, associated with the remains of extinct species, in beds of the Quaternary period deposited at a time when the Somme ran at a level more than 100 feet higher than at present, and was only beginning to excavate its valley.

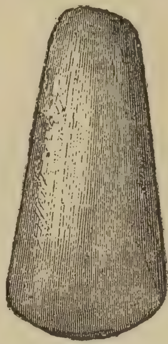
The spell once broken evidence poured in from all quarters, and although twenty-five years only have elapsed since Mr. Prestwich's paper was read, the number of stone and other implements worked by man, deposited in museums, is already counted by tens of thousands, and they have been found from Devonshire to India, in France, England, Germany, Spain, Italy, Greece, Northern Africa, Palestine, and Hindostan, and in fact wherever they have been looked for, except in northern countries which were buried under ice during the Glacial period. Some idea of the immense number of these rude implements may be formed from the fact that the valley system of one small river, the Little Ouse, which rises near Thetford and flows into the Wash after a course of twenty-five miles, has within little more than ten years yielded about 7,000 specimens.

FLINT HACHE.
From Hoxne, Suffolk.
(Half the actual size.)
(From Lubbock's "Prehistoric Times.")

They have been found in great abundance in the valley gravels of the Thames, Ouse, Wiltshire Avon, and in fact in all the river gravels and brick-earths of the south and south-east of England; and in those of the Somme, Oise, Seine, Loire, and all the principal river systems of France; and in less numbers, probably because they have been less looked for, in similar situations over an area extending from Central and Southern Europe to Madras and China. It is a remarkable fact about these river-drift implements that they are all nearly of the same type and found under similar circumstances, that is to say, in the gravels, sands, brick-earths, and fine silt or loess deposited by rivers which have either ceased to run, or which ran at levels higher than their present ones and were only beginning to excavate their present valleys. Also they are always found in association with remains of what is known as the quaternary, as distinguished from the recent or existing fauna, and which is characterized by the mammoth, the thick-nosed rhinoceros, and other well-known types of extinct animals. The general character of these implements is very rude, implying a social condition at least as low as that of the Australian savages of the present day. They consist mainly of the flake; the chopper or pebble, roughly chipped to an edge on one side; the scraper, used probably for preparing skins; pointed flints used for boring, and by far the most abundant and characteristic of all, the *hâche* or celt, a sharp or oval implement, roughly chipped from flint or, in its absence, from any of the hard stones of the district, such as chert or quartzite, and intended to be held in the hand and used without any haft or handle.

These *hâches* are evidently the first rude type of human tools,

from which the later forms of the axe, adze, chisel, wedge, etc., have been derived by a very slow and lengthened process of evolution. They differ, however, in many essential respects, from the more perfect stone celts of later periods and of modern savages. The chipping is very rude, they are never ground or polished, the pointed end is that intended for use, the butt-end being left blunt, showing that the *hâche* was not hafted but held in the hand; while the converse is always the case with the finely-chipped or polished stone celts and hatchets of the Neolithic period, which, in its later stages, are to all intents and purposes similar to modern implements, only made of stone instead of metal. But these Palæolithic *hâches* are only one step in advance of the rude natural stone which an intelligent orang or chimpanzee might pick up to crack a cocoa-nut with, or to grub up a root from the earth, or an insect from a rotten tree.



POLISHED STONE AXE. Neolithic. (Half the actual size.) (From Lubbock's "Prehistoric Times.")

At the same time there is not the remotest doubt as to their being the work of human hands. When placed side by side with the rudest forms of stone hatchets actually used by the Australian and other savages, it is difficult to detect any difference. If placed in an ascending series, from the oldest and rudest, to the finely-finished axes and arrow-heads of the period immediately preceding the use of metal, the progress may be clearly traced by insensible gradations. The blows given to bring the block to the desired shape

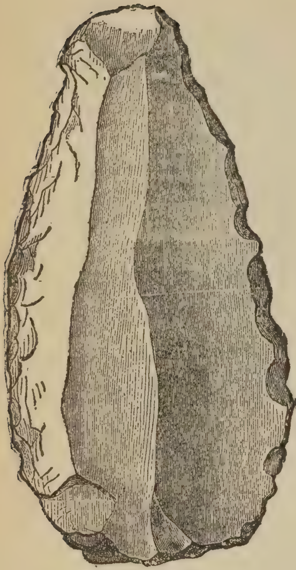
FLINT ADZE, From Danish Kitchen-middens.

MODERN STONE ADZE, New Zealand.

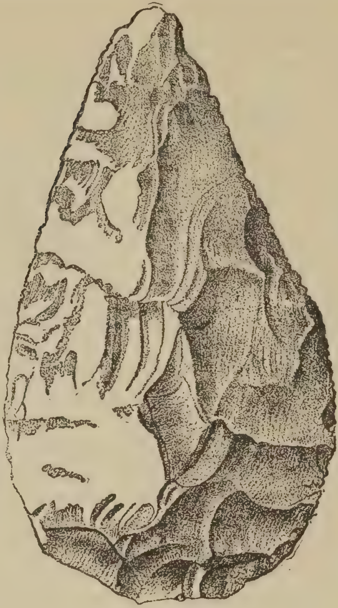
(From Lubbock's "Prehistoric Times.")

by intentional chipping have left distinct marks; and archæologists have succeeded, with a little practice, in fashioning similar implements from modern flints. In fact, forgeries have been made by workmen in localities where collectors were eager and credulous, though for-

DEVELOPMENT OF THE LANCE.



PALÆOLITHIC.
Mammoth Period.

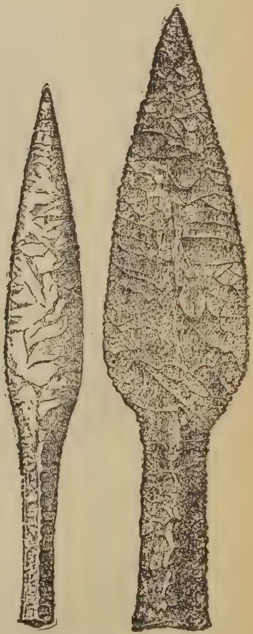


PALÆOLITHIC.
Mammoth Period.

PALÆOLITHIC.
Mammoth Period.

PALÆOLITHIC.
Reindeer Period.

EARLY NEOLITHIC.



LATE NEOLITHIC.

(From Lubbock's "Prehistoric Times.")

tunately such forgeries are easily distinguished from genuine antiques by the different appearance of the old and recent fractures, and other signs which make it almost impossible to deceive an experienced eye. The conclusion, therefore, of one of our best archæologists may be safely accepted, that it is as impossible to doubt that these rude stone flakes and hatchets are works of human art, as it would be if we had found clasp-knives and carpenters' adzes.

The remains of human skeletons are, as might be expected, very rare in these river drifts, which have been formed under conditions where the preservation of such remains would be very unlikely. In fact, as Sir John Lubbock points out, the bones found in the river gravels are almost invariably those of animals larger than man, such as the mammoth and rhinoceros. Still a few human bones have been found, sufficient to show that these river-drift men were probably a dolichocephalic or long and narrow-headed race, with prominent jaws, massive bones, and great muscular strength, but still, although rude and savage, of an essentially human type, and going a very little way towards bridging over the gap between the savage and the ape.

A more complete view, however, of the conditions of human life at these remote periods is afforded by the evidence given by caves, where naturally the remains of man are much more abundant and much better preserved. Before entering, however, on the examination of this class of evidence, it may be well to give an instance which may help to familiarize the imagination with the vast periods of time which must have elapsed since Palæolithic man left these rude implements within reach of river floods.

Among the gravels in which Palæolithic *hâches* have been found, are some which cap the cliff at Bournemouth at a height of about 130 feet above the sea. This gravel can be traced in a gradual fall from west to east, along the Hampshire coast and the shores of the Solent to beyond Spithead, and was evidently deposited by a river which carried the drainage of the Dorsetshire and Hampshire downs into the sea to the eastward, and of which the present Avon, Test, and Itchen were tributaries. But for such a river to run in such a course the whole of Poole and Christ-church bays must have been dry land, and the range of chalk downs now broken through at the Needles must have been continuous. To borrow the words Evans in the "Ancient Stone Implements," "Who, standing on the edge of the lofty cliff at Bournemouth, and gazing over the wide expanse of waters between the present shore and a line connecting the Needles on the one hand and the Ballard Down Foreland on the other, can fully comprehend how immensely remote was the epoch when what is now that vast bay was high and dry land, and a long range of chalk downs, 600 feet above the sea, bounded the horizon on the south? And yet this must have been the sight that met the eyes of those primeval men who frequented the banks of that ancient river which buried their handiworks in gravels that now cap the cliffs, and of the course of which so strange but indubitable a memorial subsists in what has now become the Solent Sea."

Any attempt to assign a more precise date than the vague one of immense antiquity to these early traces of primeval man, had better be postponed until we have examined the more detailed and extensive body of evidence which has been afforded by the exploration of caves, to which the great discovery at Abbeville at once gave an immense

impulse, and which has since been prosecuted in England, France, Belguim, and Germany, with the greatest ardor and success.

The caves in which fossil remains are found occur principally in limestone districts. They are due to the property which water possesses, when charged with a small quantity of carbonic acid, of dissolving lime. Rain falling on the earth's surface takes up carbonic acid from contract with vegetable matter, and a portion of it finds its way through cracks and crevices in the subjacent rock to lower levels, where it comes out in springs of hard water charged with carbonate of lime from the rock which it has dissolved. It has been calculated that the average rainfall on a square mile of chalk thus carries away about 140 tons of solid matter in a year. In this way underground channels are formed, some of which become large enough to admit of streams flowing through them, and even rivers, as is seen in the limestone district of Carinthia, where considerable rivers are swallowed up and run for miles beneath the surface. In this way caverns are formed, or sometimes a series of caverns, which represent the pools of the rivers which formerly flowed through them. Accumulations were formed at the bottom of these pools of whatever may have been brought down by the stream, and when, owing to changes in level or denudation of the gathering grounds, the rivers ceased to flow in the old channel, these pools became dry and were converted into caves, in which wild beasts and man found shelter and left their remains. The *débris* thus formed accumulated with a mixture of blocks which fell from the roof, and of red loamy earth consisting of the residue of the limestone rock insoluble in water, and of dust and mud brought in by winds and floods, and occasionally interstratified by beds of stalagmite, composed of thin films of crystalline carbonate of lime, deposited drop by drop by drippings through the rock forming the roof of the cave. These drippings form what are called stalactites, which hang like pendent icicles from the roof of caves, and as the drip falls from these it forms a corresponding deposit, known as stalagmite, on the floor below. The formation of this deposit is necessarily extremely slow, and it only goes on when the drops of water charged with a minute excess of carbonate of lime come in contact with the air; so that whenever the floor of the cave was under water no stalagmite could be formed. The alternations, therefore, of deposits of stalagmite represent alternations of long periods during which the cave was generally dry or generally flooded. During the dry periods, when the cave happened to be inhabited, the treadings on the floor would prevent the accumulation of an unbroken deposit of pure stalagmite, and the crystalline matter would be employed in forming a solid cement of the various *débris* into what is known as a breccia.

Another class of caves, or rock-shelters, has been formed along the sides of valleys bounded by cliffs, where the stratification is horizontal or nearly so; but the different beds vary much in hardness and permeability to water. The softer strata weather away more rapidly than the others, and thus form shallow caves or deep recesses in the face of the cliffs, with a floor of hard rock below and a roof of hard rock above, which afford dry and commodious shelters for any sort of animal, including man. In other respects they resemble the first class of caves in having their contents cemented into a breccia by the dripping of water charged with carbonate of lime from the roof, and, if the cave happened to be deserted for a long period, this deposit would in the same

way form a bed of stalagmite and seal up securely everything below it. In some cases, also, the roof would fall in, and thus preserve everything previously existing in the cave for the investigation of future geologists.

With these general remarks readers will be able to understand the evidence afforded by the remains of man found in caverns. I will begin by taking as a typical case that of Kent's Cavern, near Torquay, because it is one of the earliest and best known, and all the facts concerning it have been verified by explorations carefully conducted by a committee appointed by the British Association in 1864, and which comprised the names of the most eminent authorities in geology and palæontology, including those of Sir Charles Lyell, Sir John Lubbock, Mr. Evans, Mr. Boyd Dawkins, Mr. Pengelley, and others.

The cave is about a mile east from Torquay harbor, and runs into a hill of Devonian limestone in a winding course, expanding into large chambers connected by narrow passages. The following is the series of deposits in descending order in the large chamber near the entrance:

1. Large blocks of limestone which have fallen from the roof.
2. A layer of black, muddy mould, three inches to twelve inches thick.
3. Stalagmite one foot to three feet thick.
4. Red cave-earth with angular fragments of limestone of variable thickness, but in places five to six feet thick.

In the black earth above the stalagmite were found a number of relics of the Neolithic or polished stone period, with a few articles of bronze and pottery, some of which appear to be of a date as late as that of the Roman occupation of Britain. Associated with these are bones of ox, sheep, goat, pig, and other ordinary forms of existing species, and there is an entire absence of any older fauna, or of any of the ruder forms of Palæolithic implements. When we get below the stalagmite into the underlying cave-earth, the case is entirely reversed. Not a single specimen of polished or finely-wrought stone, or of pottery, is to be found; a vast number of celts or *hâches*, scrapers, knives, hammer stones, and other stone implements, are met with, which are all of the rude Palæolithic type found in the river drifts, with a few bone implements such as harpoon-heads, a pin, an awl, and a needle, like those frequently met with in the caves of France and Belgium. Associated with these are a vast number of bones and teeth, all of which belong to the old quaternary fauna, of which many species have become extinct and others have migrated to distant latitudes.

The following is a list of the mammalian remains which have been found in this cave-earth below the stalagmite:

ABUNDANT.

The Cave Lion, a large extinct species of lion.
Cave Hyæna, " " hyæna.
Cave Bear, " " bear.
Grizzly Bear.
Mammoth (*Elephas primigenius*).
Rhinoceros (*Tichorinus*), woolly or thick-nosed extinct species.
Horse.
Bison.
Irish Elk.

Red Deer.
Reindeer.

SCARCE.

Wolf.
Fox.
Glutton.
Brown Bear.
Urus.
Hare.
Lagomnys, tailless Arctic hare.
Water Vole.
Field Vole.
Bank Vole.
Beaver.
And one specimen of the Machairodus, or Great Sabre-toothed Tiger, which is one of the characteristic species of the upper Miocene and Pliocene formations.

These constitute a fauna which is characteristic of the Pleistocene, Quaternary, or Palæolithic period, and essentially different from that of the prehistoric or Neolithic period, which is practically the same as that now existing. Wherever remains of the mammoth, woolly rhinoceros, and cave bear are found, Palæolithic implements may be expected, and conversely. In fact Palæolithic man is as essentially part of the characteristic fauna of the Quaternary period, as the Palæotherium is of the Eocene, or the Deinotherium and Hipparion of the Miocene.

A large number of other caves have been explored in England, notably the Victoria Cave near Settle in Yorkshire, the Gower Caves in South Wales, the Brixham Cave in Devonshire, the Woking Cave in Somersetshire, and King Arthur's Cave in Herefordshire, and the results have been everywhere practically the same as those at Kent's Cavern. The same class of implements have been found and the same fauna, with the occasional addition of a few species, among which the hippopotamus is the most remarkable. Everywhere there is the same entire break between the Neolithic and the Palæolithic deposits, and the same evidence of great antiquity for the latter. It would appear as if in the British area some great geological change, such as submergence beneath the sea or invasion of the ice, had exterminated or driven away Palæolithic man, along with the mammoth, rhinoceros, cave bear, and other extinct animals of the Palæolithic fauna, and after a long lapse of time the area had again become habitable and been occupied by a newer race and by the recent fauna.

The same remark applies to the river drifts, which not in England only, but everywhere, appear to belong to a distinct period, vastly more ancient than any of the recent deposits in which Neolithic remains are found. So far, therefore, as the river drifts and British caves are concerned, all that we could say of the Palæolithic period is that it is of vast antiquity, and must have lasted for an immense time, as it was in force for the whole time requisite for rivers like the Somme or Avon, which drain small areas, to cut down their present valleys, often two or three miles wide, from the level of their upper gravels, which are in many places 100 to 150 feet above the level of the highest floods of the present rivers.

But the caves of France and Belgium supply us with more evidence, and enable us to trace the history of long periods of Palæolithic time, and study in detail the succession of changes that have occurred, and

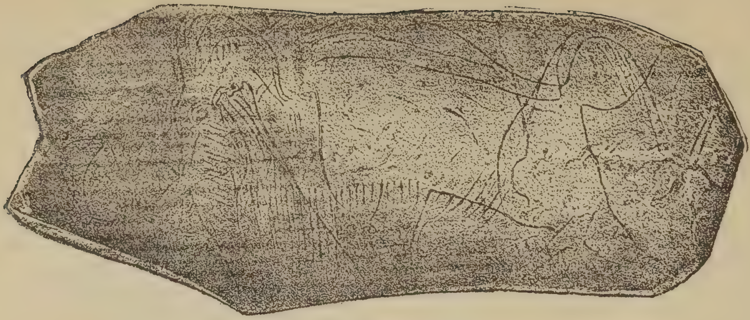
the habits, arts, and industries of the various tribes of primitive men who occupied these caves and rock-shelters at these remote periods. In fact, it may be said with truth that we know more about the men who chased the mammoth and reindeer in the South of France perhaps 50,000 years ago, than we do about those who lived there immediately before the classical era, or less than 5,000 years ago.

In certain provinces of France and Belgium it happens fortunately that there are extensive districts of limestone, in which caverns and rock-shelters are extremely abundant and full of Palæolithic remains in an excellent state of preservation. The abundance of such caves may be estimated from the fact that the cliffs, bounding one small river, the Vezère, in the department of Dordogne in the South of France, contain in a distance of eight or ten miles no fewer than nine different stations, each of which has given a vast variety of remains embedded in the breccias and cave-earths of their respective floors; and the small river Lesse in Belgium has been scarcely less prolific. Of the abundance of the human and animal remains found in such caverns it may be sufficient to say that one alone, that of Chaleux in the valley of the Lesse, is computed by Dumont to have yielded not less than 40,000 distinct objects.

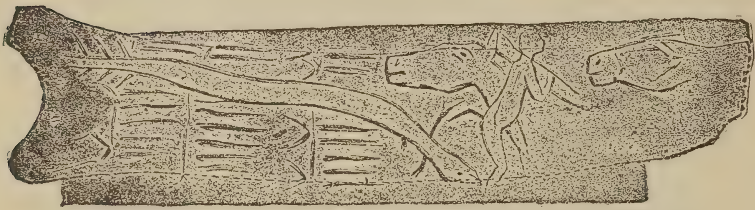
The great abundance of remains thus collected, both of human bones and implements, and of animals contemporaneous with them, have made it possible to classify and arrange, in relative order of time, a good many of the subdivisions of the Palæolithic period. This has been done partly by the order of superposition and partly by the greater or less rudeness of the implements of stone and bone, and by the greater or less abundance of those animals of the quaternary fauna which appeared first and disappeared soonest. The result has been to show that the period when vast herds of reindeer roamed over the plains of Southern France up to the Pyrenees was not the earliest, but was preceded by a long period when the reindeer was scarce, and the remains of the mammoth, cave bear, and cave hyæna were more abundant than in the following ages. The implements of this period are of the earlier river-drift type and extremely rude, and there is an almost entire absence of instruments of bone.

Gradually as we pass upwards the more Southern forms of elephant, rhinoceros, antelopes, and great carnivora disappear, and the mammoth and cave bear become scarcer, while the reindeer becomes more and more abundant until at length it furnishes the chief source of food, and its horns one of the principal materials for the manufacture of implements. Concurrently with this change we find a progressive improvement in the arts of life, as shown by stone implements more carefully chipped into a greater variety of forms, and arrow and lance-heads, barbed harpoons, awls, and needles for sewing skins, made chiefly from the antlers of the reindeer.

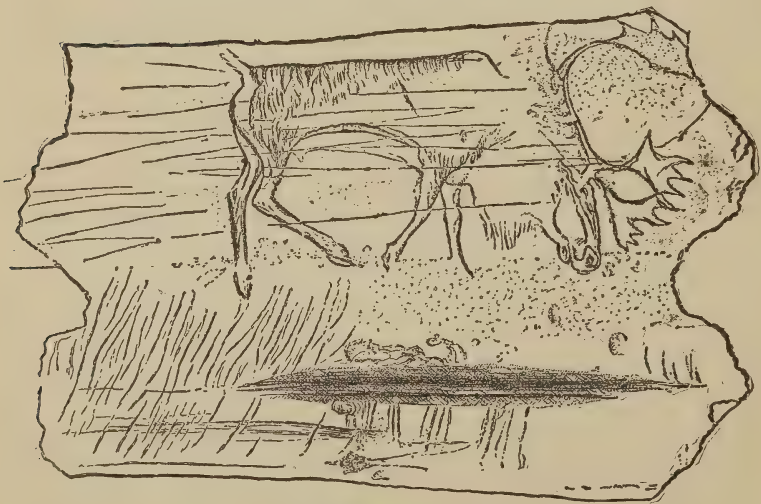
At length we arrive at one of the most interesting facts disclosed by these researches, that during one of the later or reindeer periods of the Palæolithic era, many of the caves in the South of France, and also in Switzerland and Southern Germany, were occupied by a race who, like the Esquimaux of the present day, had a strong artistic tendency, and were constantly drawing with the point of a flint on stone or bone, or modeling with flint knives from horns and bones, sketches of the animals they hunted, scenes of the chase, or other objects which struck their fancy. These are exceedingly well done,



PORTRAIT OF MAMMOTH.
Drawn with a flint on a piece of Mammoth's ivory; from Cave of La Madeleine, Dordogne, France.



EARLIEST PORTRAIT OF A MAN, WITH SERPENT AND HORSES' HEADS.
From Grotto of Les Eyzies. Reindeer Period.



REINDEER FEEDING.
From Grotto of Thayngen, near Schaffhausen, Switzerland.

so that there is no difficulty in recognizing the animals intended to be represented, among which are the mammoth, cave bear, reindeer, wild horse, and wild ox. The sketch of the mammoth which is engraved on a piece of ivory, from the cave of La Madeleine in the valley of the Vezère, is particularly interesting, as it corresponds exactly with the mammoth whose body was found entire in frozen mud on the banks of a river in Siberia, and it sets at rest all possible question of man having been really contemporary with this extinct animal in the South of France.

The drawings and carvings of other animals, especially of the reindeer, are often extremely spirited, and one especially of a reindeer engraved on a bit of bone from a cave at Thayngen, near Schaffhausen in Switzerland, would do credit to any modern animal painter. A very few human figures are found among these primeval drawings, but strangely, while the animals are so well drawn, those of men are very inferior and almost infantine in execution. They are sufficient, however, to show that the savage of Périgord pursued the formidable aurochs, naked, armed with a lance or javelin, bearded on the chin but not on the rest of the face, and wearing his hair in a tuft on the top of the head.

We do not, however, depend on these drawings for evidence of the sort of men who inhabited these caves in Palæolithic days. A large

Mentone Skeleton. Palæolithic. Reindeer Period.

number of skulls and complete skeletons have been found in different caves, some of which have served as sepulchral vaults for families and tribes, while in others individuals have been crushed by falls of rock, or otherwise interred, and in a few cases skulls and bones have been found at great depths in river drifts, and in the loess, or fine glacial mud which fills up the valley of the Rhine and other areas over which the great Swiss glaciers when melting poured their turbid streams.

The most celebrated of these are:

The Neanderthal and Canstadt skulls, which are considered to belong to the oldest type, having been found in the lowest strata, which contain the rudest implements and the most archaic fauna. Of

these the Neanderthal skull has attracted much attention from its singularly brutal appearance, having a very low and receding forehead, and a massive bony ridge over the eyes resembling that of the gorilla. But the brain is of fair capacity, and occasional skulls of a similar type occur at the present day, so that we are not warranted in saying that we have discovered the "missing link" between man and ape, especially as the Engis and other skulls of this period present less exceptional features. All we can safely say is that the oldest type of man known to us seems to have been characterized by long and narrow heads, prominent eyebrows, medium stature, and great thickness of bones and prominence of ridges denoting great muscular strength.

The discovery of a sepulchral chamber at Cro-Magnon in the valley of the Vezère, with several entire skeletons, gave evidence of another type which has been found elsewhere in caves of the same age, viz., newer than the earliest mammoth and cave bear age to which the oldest skulls are referred, but older than the subsequent reindeer age, and still characterized by great rudeness of implements. This is a remarkable type, for these savages were really a fine race of men, tall in stature and with well-developed brain. They are long-headed, but not more so than is often found in the best modern European skulls, and the average capacity of the skull exceeded that of most modern races, while their average height was not less than 5 ft. 10 in. for the men, and 5 ft. 6 in. for the women.

Another totally different race appears in caves of the same period or a little later, which is known as the Furfooz race, from a sepulchral cave in Belgium where a number of skeletons were discovered, but which appears to have been widely spread throughout Europe towards the middle of the Palæolithic period. The type of this race is almost exactly that of the modern Lapp, short in stature, averaging not above 5 ft., though strong and muscular, and with small round heads and high cheek bones. From this time forward, long and short-headed races, and intermediate types resulting probably from their intermixture, seem to have existed pretty much as they do at the present day, and the important conclusion to be drawn is, that even as far back as the early Glacial period, man had already existed long enough to develop different races, and in sufficient numbers to scatter wandering tribes of savage hunters widely over the earth and up to the verge of glaciers and the utmost confines of inhospitable regions.

In trying to fix anything like definite dates for man's existence upon earth, we must reverse the process by which we have proved the enormous antiquity of his earliest remains, and ascend step by step from the known to the unknown. The first step is that supplied by history.

Authentic Egyptian history begins with Menes, the first king who united the different provinces of Egypt into one empire.

The date of this event has been fixed by the best authorities, who have devoted their lives to the study of Egyptian texts and monuments, at about 5,000 years B.C., or say 7,000 years before the present time. Boeck makes it B.C., 5702, Unger 5613, Mariette 5004, Brugsch 4455, Lauth 4157, Lepsius, 3892, and Bunsen 3623.

It will be observed that the tendency of all the more recent investigations is to lengthen the date, and that of Mariette may be safely assumed as the *minimum* limit of time for the foundation of the Egyptian monarchy.

Now this date shows no trace of approach to a primitive and uncivilized state of things. On the contrary, Menes is related to have carried out a great engineering work by which the Nile was embanked, its course changed, and the new capitol city of Memphis built on the site reclaimed. His next successor, Tet, is credited with having written learned treatises on medicine and anatomy, and the earliest pyramid, that of Sakkara, was probably built by a king who ascended the throne only eighty-eight years after the death of Menes.

The annals and monuments of Chaldæa and China take us back to about 2,500 years B.C., or say for 4,500 years from the present time, and tell the same tale as those of Egypt of dense population and a high degree of civilization already established. In fact, it is evident that the great alluvial valleys of rivers such as the Nile and Euphrates have been inhabited for a number of centuries by a population who had emerged from the hunter and pastoral stage into that of agriculture, and had increased and multiplied until great cities were built and mighty monarchies founded, and who were in possession of most of the arts of civilized life. The Egyptian date which carries us back about 7,000 years is, however, by far the earliest upon which we can rely as an authentic record, and any glimmerings of history beyond this are obviously mythical.

Here, then, we take leave of history, and must explore our way upwards by the aid of archæology and geology.

The earliest historical civilizations were all acquainted with metals, chiefly in the form of bronze, which is an alloy of copper and tin, very hard, easily cast, and well adapted for every description of tool and weapon. Indeed, it has only been superseded by iron within recent historical times. But the Bronze Age was preceded by a long Neolithic period, when stone, finely wrought and often ground or polished, was used for the purposes to which metal was afterwards applied. The men of this Neolithic period were comparatively civilized; they had all the common domestic animals, the dog, horse, ox, sheep, goat, and pig; also some of the cultivated grains, as wheat and barley; they wore clothing and lived in villages. According to all appearance they were the first wave of the great migrations into Europe from Asia, and either occupied regions left empty by the last vicissitudes of the Glacial period, or conquered, and partly exterminated and partly intermixed with, the ruder savages of the Palæolithic period. Some think the Iberian or Basque people may be a remnant of this Neolithic race, who were driven westward by the later wave of Celtic migration just as the Celts were by the still later waves of Teutonic and Slavonic immigrants. Be this as it may, it is certain that a Neolithic people were spread very widely over the globe, as their remains of very similar character are found almost everywhere in Europe, Asia, and America, and always in association with the existing or most recent fauna and configuration of the earth's surface.

The difficulty in assigning any precise date for these remains arises very much from the fact that the Neolithic passed into the Bronze or historical civilization, at different times in different countries. The Australians, the Polynesians, and the Esquimaux were or are still in the Stone period, while steam-engines are spinning cotton at Manchester, and the most famous cities of Egypt and the East have been for centuries buried under shapeless mounds of their own ruins. It is probable that all Europe remained in the Neolithic stage for

many centuries after the historical date of the commencement of the Egyptian empire.

Still there are some remains which may enable us to form an approximate conjecture of the time during which this Neolithic period may have lasted.

The two principal clues are furnished:

1. By the Danish mosses and kitchen-middens.
2. By the Swiss lake-dwellings.

In Denmark there are a number of peat mosses varying in depth from ten to thirty feet, which have been formed by the filling up of small lakes or ponds in hollows of the Glacial drift. Around the borders of these mosses, and at various depths in them, lie trunks of trees which have grown on their margin. At the present surface are found beech-trees, which are now, and have been throughout the whole historical period of 2,000 years, the prevalent form of forest vegetation in Denmark. Lower down is found a zone of oaks, a tree which is now rare and almost superseded by the beech. And still lower, towards the bottom of the mosses, the fallen trees are almost entirely Scotch firs, which have been long unknown in Denmark and when introduced will not thrive there. It is evident, therefore, that there have been three changes of climate, causing three entire changes in the forest vegetation of Denmark, since these mosses began to be formed. The latest has lasted certainly for 2,000 years and we cannot tell how much longer, so that some period of more than 6,000 years must be assumed for the three changes.

Now, it is invariably found that remains of the Iron Age are confined to the present or beech era, while bronze is found only in that of oak, and the Age of Stone coincides with that of the Scotch fir.

The kitchen-middens afford another memorial of the prehistoric age in Denmark. There are mounds found all along the sheltered sea-coasts of the main-land and islands, consisting chiefly of shells of the oyster, cockle, limpet, and other shell-fish, which have been eaten by the ancient dwellers on these coasts. Mixed up with these are the bones of various land animals, birds, and fish, and flint flakes, axes, worked bones and horns, and other implements, including rude hand-made pottery, The relics are very much the same as those found in the fir zone of the peat mosses, and although old as compared with the Iron or historical age, they do not denote any extreme antiquity. The shells are all of existing species, though the larger size of some of those found on the shores of the Baltic shows that the salt water of the North Sea had then a freer access to it than at present. The bones of animals, birds, and fish are also all of existing species, and no remains of extinct animals, such as the mammoth, or even of reindeer, have been found. By far the most common are the red deer, roe-deer, and wild boar. The dog was known, but appears to have been the only domestic animal.

Most of the stone implements are rude, but a few carefully-worked weapons have been found, and a few specimens of polished axes, which, with the presence of pottery and the nature of the fauna, show conclusively that these Danish remains are all of the Neolithic age and subsequent to the close of the Glacial period. In fact, similar shell mounds are found in almost all quarters of the globe where savage tribes have lived on the sea-coast, subsisting mainly on shell-fish, and they are probably still being formed on the shores of the

Greenland and Arctic Seas, and in Australia, and remote islands of the Pacific.

Human remains are scarce in these Danish deposits, but numerous skulls and skeletons have been found in tumuli which, from their situation and from stone implements being buried with the dead, may be reasonably inferred to be those of the people of the peat mosses and shell mounds. They denote a short race with small and very round heads, in many respects resembling the present Lapps, but with a more projecting ridge over the eye.

On the whole, all we can conclude from these Danish remains is that at some period, not less than 6,000 or 7,000 years ago, when civilization had already been long established in the valley of the Nile, rude races resembling the Lapps or Esquimaux lived on the shores of the Baltic, who, although so much more recent, and acquainted with the domestic dog, pottery, and the art of polishing stone, had not advanced much beyond the condition of the later cave-men of the South of France; and that this race was succeeded by one who brought in the much higher civilization of the Bronze Age.

The lake-dwellings of Switzerland give still more detailed and interesting information as to Neolithic times.

During a very dry summer in 1854, the Lake of Zurich fell below its usual level and disclosed the remains of ancient piles driven into the mud, from which a number of deer-horns and other implements were dredged up. This led to further researches, and the result has been that a large number of villages built on these piles has been discovered in almost all the Swiss lakes, as well as in those of Italy and other countries. On the whole, more than 200 have been discovered in Switzerland, and fresh ones are being constantly brought to light. They range over a long period, a few belonging to the Iron and even to Roman times; while the greater number are almost equally divided between the Age of Bronze and that of Stone. Some of them are of large size, and must have been long inhabited and supported a numerous population, from the immense number of implements found, which at one station alone, that of Concise on the Lake of Neufchâtel, amounted to 25,000. These implements consist mainly of axes, knives, arrow-heads, saws, chisels, hammers, awls, and needles, with a quantity of broken pottery, spindle-whorls, sinkers for nets, and other objects.

In the oldest stations, where no trace of metal is found, and the decay of the piles to a lower level shows the greatest antiquity, the implements are all of the Neolithic type, and the animal remains associated with them are all of the recent fauna. There are no mammoths, rhinoceroses, or reindeer; the wild animals are the red deer and roe, the urus, bison, elk, bear, wolf, wild cat, fox, badger, wild boar, ibex, and other existing species; and of domestic animals, the dog, pig, horse, goat, sheep, and at least two varieties of oxen. Birds, reptiles, and fish, were all of common existing species. Carbonized ears of wheat and barley have been found, as also pears and apples, and the seeds, stones, and shells of raspberry, blackberry, wild plum, hazel-nut, and beech-nut. Twine, and bits of matting made of flax, as well as the occurrence of spindle-whorls, show that the pile-dwellers were acquainted with the art of weaving.

On the whole, these pile-villages show that a large population lived in Switzerland for a long time before the dawn of history, who had already attained a considerable amount of civilization at their

first appearance, which went on steadily increasing down to the time of the Roman conquest. Various attempts have been made to fix an approximate date for the earliest of these pile-villages, but they have not been very successful. They have been based mainly on the amount of silting up which has taken place in some of the smaller lakes since the piles were driven in, as compared with that which has occurred since the Roman period. The best calculations appear to show that 6,000 or 7,000 years ago Switzerland was already inhabited by men who used polished stone implements, but how long they had been there we had no distinct evidence to show. Perhaps 10,000 years may be taken as the outside limit of time that can be allowed for the Neolithic period in Switzerland, Denmark, or any known part of Europe.

In Egypt, however, there is evidence of a much greater antiquity. Fragments of pottery, which was entirely unknown in the Palæolithic age, have been brought up by borings in the Nile Valley from depths which, at the average rate of accumulation there during the last 3,000 years of three inches and a half in a century, would denote an age of from 13,000 to 18,000 years. Looking at the dense population and high civilization of Egypt at the commencement of history, 7,000 years ago, it is highly probable that this time at least must have elapsed since the country was first occupied by a settled agricultural population as far advanced in the arts of life as the lake-dwellers of Switzerland.

Any calculation, however, of Neolithic time takes us back a very short step in the history of the human race. The Palæolithic period must evidently have been of vastly longer duration.

Any attempt to estimate this must depend entirely on geological considerations. Palæolithic man is part of the Quaternary fauna, which came in with the commencement and continued down to the close of the great Glacial period.

In carrying our researches further back, the possibility of assigning anything like a definite date for the existence of man depends, therefore, on the question whether it is possible to fix any approximate dates for the commencement and duration of this period.

In the first place, how do we know that there has been a Glacial period?

In England we are familiar with water, but not with ice; we therefore recognize at once the signs of the action of water. If we come across a dry channel, winding in alternating curves between eroded banks, and showing deposits of gravel and silt, we say without hesitation, "Here a river formerly ran." But if we had lived in Switzerland, we should recognize with equal certainty the signs of glacial action. Suppose any one visiting Chamouni walks up the valley to the foot of the Mer de Glace, where the Arve issues from the glacier, let us say in autumn, when the front of the glacier has shrunk back some distance, what does he see? Rounded and polished rocks, which seem as if they had been planed by a gigantic plane working downwards over them, and on these a mass of miscellaneous rubbish shot down as if from a dust-cart, consisting of stones of all sizes, some of them boulders as big as a house, scattered irregularly on a mass of clay and sand. When he looks more closely he will see that these stones are not rounded as they would be by running water, but blunted at their angles by a slow grinding action; and in many cases, both the stones

and the rocks on which they rest are scratched and striated in a direction which is that of the glacier's motion. At the bottom of this rubbish-heap he will find the clay into which the rock has been ground by the full weight of the glacier, very stiff and compact; while if he look down the valley, he will see, on a hot day, a swollen and turbid river issuing from the melting ice and flooding the meadows, on which it will leave a deposit of fine mud. These are effects actually produced by ice; and wherever he sees them he can infer the former presence of glacier. as certainly as when he sees a bed of rounded pebbles he infers the former presence of running water. The planed rocks are commonly known as *roches moutonnées* from a fancied resemblance of their smooth, rounded hummocks to the backs of a flock of sheep lying down; the rubbish-heaps are called *moraines;* and the stiff bottom clay with boulders embedded in it is called the *grund-moraine*, till, or boulder clay; while the blunted and scratched stones are said to be glaciated.

These tests, therefore, *roches moutonnées*, moraines, boulders, and glaciated stones, are infallible proofs that whevever we find them there has been ice-action, either in the form of glaciers, or of icebergs, which are only detached portions of glanciers floated off when the glacier ends in the sea. Now, if our inquirer extends his view, he will find that these signs, the meaning of which he has learned at the head of the valley of Chamouni, are to be found equally in every valley and over the whole plain of Switzerland, up to a height of more than 3,000 feet on the slope of the opposite Jura range, while on the Italian side the Glacial drift extends far into the plains of Piedmont.

Extending our view still more widely, we find that every high mountain range in the Northern hemisphere has had its system of glaciers; and one great mountain mass, that of Scandinavia, has been the nucleus of an enormous ice-cap, radiating to a distance of not less than 1,000 miles, and thick enough to block up with solid ice the North Sea, the German Ocean, the Baltic, and even the Atlantic up to the 100 fathom line. This ice-cap, coalescing with local glaciers from the higher lands of England, Scotland, and Ireland, swept over their surface, regardless of minor inequalities of hill and valley, as far south as to the present Thames Valley, grinding down rocks, scattering drift and boulders, and, in fact, doing the first rough sub-soil ploughing which prepared most of our present arable fields for cultivation. The same ice-sheet spread masses of similar drift over Northern Germany, Sweden, Denmark, and the northern half of European Russia, and left behind it numerous boulders which must have traveled all the way from Norway or Lapland.

If we cross the Atlantic we find the same thing repeated on a still larger scale in North America. A still more gigantic ice-cap, radiating from the Laurentian ranges, which extend towards the pole from Canada, has glaciated all the minor mountain ranges to the south up to heights sometimes exceeding 3,000 feet, and coalescing vast glaciers thrown off by the Rocky Mountains from their eastern flanks, has swept over the whole continent, leaving its record in the form of drift and boulders, down to the 40th parallel of latitude. It is difficult to realize the existence of such gigantic glaciers, but the proofs they have left are incontrovertible, and we have only to look to Greenland to see similar effects actually in operation. The whole of that vast country, where at former periods of the earth's history,

fruit-trees grew and a genial climate prevailed, is now buried deep under one solid ice-cap, from which only a few of the highest peaks protrude, and which discharges its surplus accumulation of winter snow by huge glaciers filling all the fiords and pushing out into the sea with an ice-wall sometimes forty or fifty miles in length, from which icebergs are continually breaking off and floating away. A still more gigantic ice-wall surrounds the Southern Pole, and in a comparatively low latitute presented an insuperable barrier to the further progress of the ships of Sir J. Ross's expedition.

A still closer examination of the Glacial period shows that it was not one single period of intense cold but a prolonged period, during which there were several alternations, the glaciers having retreated and advanced several times with comparatively mild inter-glacial periods, but finally with a tendency on each successive advance to contract its area, until the ice shrank into the recesses of high mountains, where alone we now find it. Another noteworthy point is that during this long Glacial period there were several great oscillations in the level of sea and land.

Such was the Glacial period, and to assign its date is to fix the date when we know with certainty that man already existed, and had for some long though unknown time previously been an inhabitant of earth. Is this possible? To answer this question we must begin by considering what are the causes, or combination of causes, which may have given rise to such a Glacial period. When we look at the causes which actually produce existing glaciers, we find that extreme cold alone is not sufficient. In the coldest known region of the earth, in Eastern Siberia, there are no glaciers, for the land is low and level and the air dry. On the other hand, in New Zealand, in the latitude of England and with a mean annual temperature very similar to that of the West of Scotland, enormous glaciers descend to within 700 feet of the sea-level. The reason is obvious; the Alps of the South Island rise to the height of 11,000 feet above the sea, and the prevalent westerly winds strike on them laden with moisture from their passage over a wide expanse of ocean. In like manner, in the case of the Swiss Alps, the Himalayas, and other great mountain ranges, high land and moist winds everywhere make glaciers. Given the moist wind, any great depression of temperature, whether arising from elevation of land or other causes, will make it deposit its moisture in the form of snow, and the accumulation of snow on a large surface of elevated land must inevitably relieve itself by pushing down rivers of ice to the point where it melts, just as the rain-fall relieves itself by pouring down rivers to the point where the surplus water finds its level in the sea.

When the two conditions of high land and moist winds are combined, low temperature increases their effect, and the snow-fall consolidates into a great ice-cap, from which only the tops of the highest mountains project, and which pushes out gigantic glaciers far over surrounding countries and into adjacent seas. Such is now the case in Greenland, and was formerly the case in Scandinavia, where a huge sheet of ice radiated from it over Northern Germany as far as Dresden, filled up the North Sea, and, coalescing with smaller ice-caps from the highlands of Scotland, England, and Wales, buried the British Islands up to the Thames under massive ice. At the same period glaciers from the Alps filled the whole plain of Switzerland, and in North America the ice-cap extended from Labrador to Philadelphia.

The first remark to be made is that, as these phenomena depend primarily on moist winds, and only secondarily on cold, and as moist winds imply great evaporation and therefore great solar heat over extensive surfaces of water, all explanations are worthless which suppose a general prevalence of cold, either from less solar radiation, passage through a colder region of space, or otherwise. We must seek for a cause which is consistent with the general laws of Nature, and with the leading facts of the actual generation of glaciers at the present day.

Astronomers believe that they have discovered such a cause, in the theory first started by Mr. Croll, that the glaciation of the Northern hemisphere was due to a secular change in the shape of the earth's orbit, combined with the shorter changes produced by the precession of the equinoxes. The latter cause is due to the fact that the earth is not an exact sphere but slightly protuberant at the equator, and that the attraction of the sun on this protuberant matter prevents the axis round which the earth rotates from remaining exactly parallel with itself, and makes it move slowly round its mean position just as we see in the case of a schoolboy's top, which reels round an imaginary upright axis while spinning rapidly. This revolution in the case of the earth completes its circle in about 21,000 years, so that if summer, when the pole is turned towards the sun, occurred in the Northern hemisphere when the earth was in perihelion, or nearest the sun, and consequently winter when it was in aphelion, or furthest away from the sun, after 10,500 years the position would be exactly reversed, and winter would occur in perihelion and summer in aphelion; the Southern hemisphere then enjoying the same conditions as those of the Northern one 10,500 years earlier. And in another 10,500 years things would come back to their original position.

Now if the earth's orbit were an exact circle this would make no difference, all the four seasons would be of the same duration and would receive the same solar heat in both hemispheres, and if the orbit were nearly circular, so that the difference between the perihelion and aphelion distances was small, the effect would be small also. But if the orbit flattened out or became more eccentric, the effect would be increased. The time of traversing the aphelion portion of the annual orbit would become longer and that of traversing the perihelion portion shorter, as the orbit departed from the form of a circle and became more elliptic. Whenever, therefore, the North Pole was turned away from the sun in aphelion, the winters would be longer than the summers in the Northern hemisphere, and conversely, the summers would be longer than the winters when, after an interval of 10,500 years, precession brought about the opposite condition of things, in which winter occurred in perihelion.

At present the earth's orbit is nearly circular, and the Northern hemisphere is nearest the sun in winter and furthest from it in summer, but the difference is only about 3,000,000 miles, or a small fraction of the total mean distance of 93,000,000 miles, which makes the winter half of the year shorter than the summer half by nearly eight days.

But mathematical calculations show that under the complicated attractions of the sun, moon, and larger planets, the eccentricity of the earth's orbit slowly changes at long and irregular intervals, but always within fixed limits, increasing up to a certain point and then diminishing till it approaches the circular form, when it again increases.

The *maximum* limit of eccentricity makes the difference between the greatest and least distances of the earth from the sun range between 12,000,000 and 14,000,000 miles, which is four or five times as great as at present; and with this eccentricity, and winter in aphelion in the Northern hemisphere, the winter half of the year in Northern latitudes would be twenty-six days longer than the summer half, instead of eight days shorter as at present. In this state of things the quantity of heat received daily from the sun in winter would be such as to lower the temperature of the whole Northern hemisphere by 35° Fahrenheit, and reduce the average January temperature of England from 39 to 4°, while the mean summer temperature would be about 60° higher than at present. But this summer heat, derived from solar radiation, would not counteract the cold of winter, for all moisture during winter being accumulated in ice, and snow, most of the solar heat of summer would be expended in supplying latent heat to melt a portion of this frozen accumulation, and dense fogs would intercept a large amount of the solar radiation.

After 10,500 years this state of things would be entirely reversed, and with twenty-six days more of summer, and the earth 12,000,000 miles nearer the sun in winter, the Northern hemisphere would enjoy something like perpetual spring. There can be no doubt that these are real causes, and the only difficulty is to account for their not having been more invariable in their operation and given us a constant succession of Glacial periods since the commencement of geological time, whenever the eccentricity became great, which occurs at irregular periods, but practically about three times in every 3,000,000 years. The answer is that the effects would only occur when the other conditions were present, viz., high land, moist winds, and an absence of oceanic currents of warm water like the Gulf Stream. The latter is one of the main causes which affect temperature. The difference of temperature between the equatorial and polar regions causes a constant overflow of heated air from south to north, which is replaced by an indraught of colder air from north to south, which, owing to the greater velocity of the earth's rotation towards the equator, takes the form of trade-winds blowing constantly from a more or less easterly direction. These winds, sweeping over the Atlantic Ocean, raise its level at its western barrier, and the accumulation deflected by America flows off in a current which extends to the western shores of Europe and carries mild winters into the extreme North. In the Orkney and Shetland Islands, which are nearly in the same latitude as Cape Farewell in Greenland, there is so little ice that skating is a rare accomplishment, and curling, the roaring game which is so popular some degrees further south, is quite unknown. If the Gulf Stream were diverted, and the highlands of Scotland upheaved to the height of the Alps of New Zealand the whole country would again be buried under glaciers pushing out into the Atlantic and German Ocean.

These considerations may show why every period of great eccentricity was not necessarily a Glacial period, though under certain conditions it must inevitably have been so, and geologists are generally agreed that the last period of the sort must have been one of the main causes of the great refrigeration which set in over the whole Northern hemisphere towards the close of the Pliocene period, and continued until recent times. But in this case we can fix the date with great accuracy, for calculation shows that the last period of

great eccentricity began 240,000 years ago, and lasted 160,000 years. For the last 50,000 years the departure of the earth's orbit from the circular form has been exceptionally small. We may suppose the Glacial period, therefore, to have commenced 240,000 years ago, come to its height 160,000 years ago, and finally passed away 80,000 years before the present time.

These dates receive much confirmation from conclusions drawn from a totally different class of facts. A bed of existing marine shells of Arctic type, apparently belonging to one of the latest phases of the Glacial period, has been found on the top of a hill in North Wales which is now 1,100 feet above the sea-level, and the same marine drift seems to extend to a height of upwards of 2,000 feet. There must, therefore, have been a depression of the land sufficient to carry it many fathoms below the sea, and a subsequent elevation sufficient to carry the sea bottom up to a height of certainly 1,100 and probably over 2,000 feet. In all probability, these movements were very slow and gradual, like those now going on in Greenland and Scandinavia, for there are no signs of earthquakes or volcanic eruptions in the district; and it is probable that pauses occurred in the movements, and a long pause when subsidence had ceased before elevation began. Without taking these pauses into account, and assuming the elevation only just completed, and that Sir C. Lyell's average of two and a half feet a century is a fair rate for these slow movements, it would have required 50,000 years of continued elevation to bring these shells, and 80,000 years to bring the marine drifts, up to their present height above the sea; and a similar period previously must be allowed for their submergence. We may fairly conclude, therefore, that upwards of 100,000 years have elapsed since these shells lived and died at the bottom of the sea towards the close of the Glacial period, which corresponds very well with the date assigned by astronomical calculations.

Again, another attempt to fix a date for the close of the Glacial period has been made by Monsieur Forel, a Swiss geologist, from actual measurements of the quantity of suspended matter poured into the Lake of Geneva by the Rhone, and the area of the lake which has been silted up since it was filled by ice. It is evident that this silting up at the head of the lake could only begin when the great Rhone glacier, which once extended to the Jura Mountains, had shrunk back into its valley far enough to pour its river into the lake. M. Forel's calculations give 100,000 years as the probable time required for the river to silt up so much of the lake as is now converted into dry land. The data are somewhat vague, as on the one hand the rate of deposition may have been greater when a large mass of ice and snow was being melted, while on the other hand it may have been less, while the glacier still occupied the valley almost to the head of the lake and the Rhone had only a course of a few miles. All that can be said, therefore, is that it gives an approximate date for the close of the Glacial period which, like that derived from rates of depression and elevation, corresponds wonderfully well with the date required by Croll's theory.

Now, whether the date be a little more or a little less, it is clear that man existed on earth throughout a great part, if not the whole, of the Glacial period. He had existed a long while in conjunction with a fauna of more Southern and African aspect, before the reindeer migrated in vast herds into Southern France. His remains are found

in caves and river drifts associated with those of hippopotamus, an animal which could by no possibility have lived in rivers which for half the year were bound hard in ice. Such remains must therefore of necessity date either from a period before the great cold had set in, or from some inter-glacial period prior to the great cold which drove the reindeer, musk ox, glutton, and Arctic hare as far south as the slopes of the Pyrenees.

In England we can trace distinctly at least four successions of boulder clays, that is of the ground moraines of land ice, separated by deposits of drifts, sands, and brick-earths, formed while the glaciers were retreating and melting; and a number of the Palæolithic implements have been found in what was undoubtedly part of the period of the second or great chalky boulder clay, which overspreads the southern and eastern counties of England up to the Thames Valley. The discovery of Palæolithic remains in the deposit of St. Prest, near Chartres, makes it almost certain that some at least of the ruder instruments must date back to the very beginning of the Glacial period, and all the evidence points to the conclusion that man was living during the many alternations of climate of that period, and whenever the glaciers retreated, followed them up closely.

Thus far we have been going on certain and ascertained facts, confirmed by such numerous and well-authenticated proofs that doubt is impossible. But we get on less certain ground when we try to trace back human origin to more remote periods. As regards this question, we must begin by describing shortly the geological periods during which the existence of man may have been possible. It is useless to go back beyond the Chalk, which was deposited in a deep ocean and forms a great break between the modern and the Secondary period, in which latter reptiles predominated, and mammalia are only known by a few remains of small insectivorous and marsupial animals.

The inauguration of the present state of things commences with the Tertiary period. This has been divided into three stages: the Eocene, in which the first dawn appears of animal life similar in type to that now existing; the Miocene, in which there is a still greater approximation to existing forms of life; and the Pliocene, in which existing types and species become preponderant. Then comes the Pleistocene or Quaternary, including the great Glacial period, during which the whole marine and nearly the whole terrestrial fauna are of existing or recently extinct species, though very different in their geographical distribution from that of the present day. And finally we arrive at the recent period, when the present climate and the present configuration of lands, seas, and rivers, prevail with very slight modifications, and no changes have taken place either in the specific character or geographical distribution of life, except such as can be clearly traced to existing causes such as the agency of man.

This is the geological frame-work into which we have to fit the history of man's appearance upon earth. We have traced him through the recent and Quaternary, can we trace him further into the Tertiary? Speaking generally we may say that the Eocene period was that in which Europe began to assume something like its present configuration, and in which mammalian life, of the higher or placental type, began to supplant the lower forms of marsupial life which had preceded them. But these higher types were for the most part of a more primitive or generalized character than the more specialized types of

later periods, and the highest order, that of the *primates*, which includes man, ape, and lemur, was, as far as is yet known, represented only by two or three extinct lemurian forms.

The plan on which Nature has worked in the evolution of life seems always to have been this: she begins by laying down a sort of ground plan, or generalized sketch of a particular form of life, say first of vertebrata, then of fish, then of reptiles, and finally of mammalian life. This sketch resembles the simple theme of a few notes on which a musician proceeds to work out a series of variations, each surpassing the other in complication and specialized development in some particular direction. Now, in the Eocene period we are in the stage of the theme and first simple variations of the mammalian melody. It hardly seems likely, therefore, that a creature so highly specialized as man, even in his most rudimentary form, should have existed, and in the absence of any direct evidence to the contrary, it is safe to assume that his first appearance must have been of later date.

But when we come to the Miocene and Pliocene periods, the case is different. It is true that in the Miocene the specialization of certain families, as for instance that of the horse, had not been carried out to the full extent, and that all the species of Miocene land-mammals and several of the genera are now extinct. But there were already true apes and baboons, and even two species of anthropoid ape, one of which, the Dryopithecus, whose fossil remains were found in the South of France, was as large as a man, and has been considered by some anatomists as in some respects superior to the chimpanzee or gorilla.

Now, wherever anthropoid apes lived it is clear that, whether as a question of anatomical structure or of climate and surroundings, man, or some creature which was the ancestor of man, might have lived also. Anatomically speaking, apes and monkeys are as much special variations of the mammalian type as man, whom they resemble bone for bone and muscle for muscle, and the physical animal man is simply an instance of the quadrumanous type specialized for erect posture and a larger brain. The larger brain, implying greater intelligence, must also have given him advantages in contending with outward circumstances, as for instance, by fire and clothing against cold, which might enable him to survive when other species succumbed and became extinct.

If he could survive, as we know he did, the adverse conditions and extreme vicissitudes of the Glacial period, there is no reason why he might not have lived in the semi-tropical climate of the Miocene period, when a genial climate extended even to Greenland and Spitzbergen, and when ample forests supplied an abundance of game and edible fruits. The same reasons apply, with still greater force, to the Pliocene period, when existing types and species had become more common and when a mild climate still prevailed. The existence of Tertiary man must antecedently be pronounced highly probable; but probabilities are not proofs, and the fact of such existence must be determined by the evidence. All that can be said is that while there ought to be great caution in admitting as established a fact of such importance, there ought to be no determined predisposition to disbelieve it, like that which for so many years retarded the acceptance of the evidence for Palæolithic man. On the contrary, the fact that man existed in such numbers and under such conditions as have been

described in the Quaternary period, establishes a strong presumption that his first appearance must date from a much earlier period.

Let us see how the evidence stands. Undoubted stone implements, and bones bearing traces of cuttings by flint knives, have been found in strata at St. Prest, near Chartres, which were always considered to be Pliocene. Since the discovery, however, some geologists have contended that these strata are not Pliocene, but of the earliest Quaternary or perhaps a transition period between Pliocene and Quaternary. This evidence cannot, therefore, be accepted as conclusive for anything more than proof that man's existence extends at any rate over the whole Quaternary period, comprising the vast glacial and inter-glacial ages which have effected such changes in the earth's surface.

The next piece of evidence is from Italy, where bones of the Balænotus, a sort of Pliocene whale, have been discovered in strata undoubtedly Pliocene, which bear marks of incisions which to all appearance must have been made by flint knives employed in hacking off the flesh. Doubts were thrown at first on this, as it was thought that possibly fish, or some gnawing animal like the beaver, might have

Incised Bones of Balænotus. Pliocene. From Monte Aperto, Italy.
Figured by Quartrefages, "Hommes Fossiles et Hommes Sauvages," p. 93.

cut the grooves with their teeth. But later specimens have been found on which the cuts have a regular curvature which could not have been made by any teeth, and present precisely the same appearance as the cuts which are so commonly found on the bones of reindeer and other animals in hundreds of Palæolithic caves.

M. Quatrefages, who is a very eminent and at the same time very cautious authority, says, in his last work on the subject published in 1884, "Hommes Fossiles et Hommes Sauvages," that "the most incredulous must be convinced. The hand of man armed with a cutting instrument could alone have left marks of this sort on a plain surface. It is evident that some horde of savages of these remote times has found the carcase of this great cetacean stranded on the shore, and cut the flesh off with stone knives just as the savages of Australia do at the present day." In fact incredulity only exists because this is as yet a solitary instance of Pliocene man, and scientific

men, feeling that if true, further evidence must soon be found, very properly endeavor to keep their judgment in suspense.

If these bones of the Balænotus really bear marks of human tools, the spectacle which might have been witnessed on the shore of the Pliocene sea perhaps 500,000 years ago, must have closely resembled that given by Sir John Lubbock from a description by Captain Grey of a recent whale feast in Australia. "When a whale is washed on shore it is a real godsend to them. Fires are immediately lit, to give notice of the joyful event. Then they rub themselves all over with blubber, and anoint their favorite wives in the same way; after which they cut down through the blubber to the beef, which they sometimes eat raw and sometimes broil on pointed sticks. As other natives arrive they 'fairly eat their way into the whale, and you see them climbing in and about the stinking carcass, choosing tidbits.' For days 'they remain by the carcass, rubbed from head to foot with stinking blubber, gorged to repletion with putrid meat—out of temper from indigestion, and therefore engaged in constant frays—suffering from a cutaneous disorder by high feeding—and altogether a disgusting spectacle. There is no sight in the world,' Captain Grey adds, 'more revolting than to see a young and gracefully-formed native girl stepping out of the carcase of a putrid whale.'"

FLINT SCRAPER.
From Thenay. Miocene
Figured by Quatrefages.
"Hommes Fossiles et Hommes Sauvages," p. 92.

The evidence for Miocene man is much of the same character; very strong and conclusive as far as it goes, but resting on too few instances to be universally accepted. In 1868 the Abbé Bourgeois laid before the Anthropological Congress at Paris certain flints which he had found *in situ* in undoubted Miocene strata at Thenay, in the Beauce, near Blois. They were received with general incredulity, and the traces of human design were denied. The Abbé, however, persisted, and having made fresh discoveries the subject was referred to the next meeting of the Congress at Brussels, who appointed a commission of fifteen of the most eminent European authorities in such matters to report upon it. Nine reported that some of the flints showed undoubted traces of human workmanship, five were of an opposite opinion, and one was neutral. Since then fresh objects have been found and M. Quatrefages, who had formerly been doubtful, says in his recent work: "These new objects, and especially a scraper which is one of the most distinctly characterized of that class of implements, have removed my last doubts." And certainly, if the figures given at page 92 of his "Hommes Fossiles et Hommes Sauvages" correctly represent the original implements, and they really came from Miocene strata, doubt is no longer possible. The evidence of design in chipping into a determinate shape is quite as clear as in the similar class of implements from Kent's Cavern or the Cave of La Madeleine. They must either have been chipped by man, or as Mr. Boyd Dawkins supposes, by the Dryopithecus or some other anthropoid ape which had a dose of intelligence so much superior to the gorilla or chimpanzee as to be able to fabricate tools. But in this case the problem would be solved and the missing link discovered, for such an ape might well have been the ancestor of Palæolithic man.

MIOCENE IMPLEMENTS FROM THENAY COMPARED WITH UNDOUBTED PALÆOLITHIC IMPLEMENTS FROM QUATERNARY CAVES AND DRIFTS.

MIOCENE.

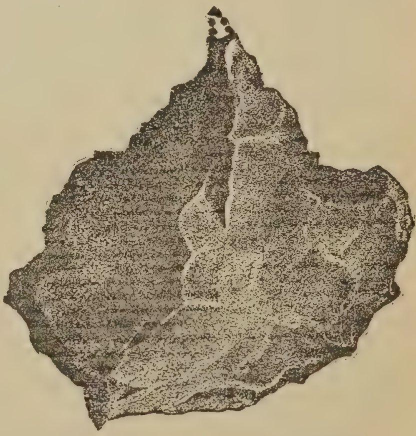
QUATERNARY. Chaleux, Belgium. Reindeer Period. Congrès Préhistorique, Bruxelles, 1872.

SCRAPER, OR RUDE KNIFE. Thenay. Miocene. Quatrefages, p. 92.

BORER, OR AWL. Thenay. Miocene. Congrès Préhistorique, Bruxelles, 1872.

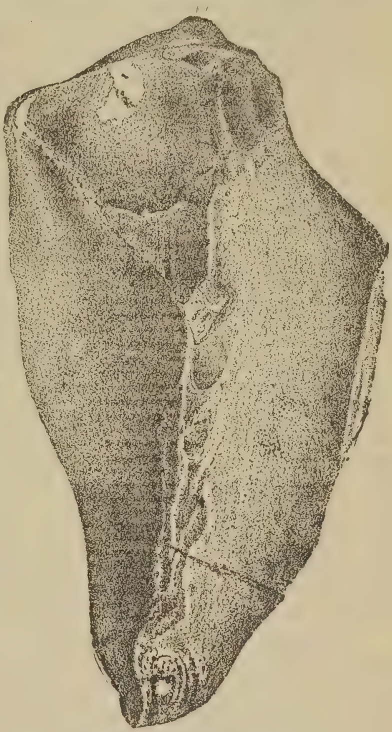
SCRAPER. Thenay. Miocene. Quatrefages, p. 92.

QUATERNARY. From Le Moustier.



QUATERNARY. Mammoth Period. River Drift, Mesvin, Belgium. Congrès Préhistorique, Bruxelles, 1872.

The next instance is from the valley of the Tagus, where flint implements were alleged to have been discovered by an eminent Portuguese geologist, Señor Ribeiro, in Miocene strata. The subject was fully discussed on the spot, at a meeting of the Anthropological Congress at Lisbon in 1880. The general opinion seemed to be that some of the implements showed undoubted traces of human design, but some good authorities remained sceptical; and although there was no doubt that they were found in Miocene strata, it was thought possible that flints of Quaternary age might have fallen into fissures, or been mixed up with Miocene sands by floods at some very remote period, and thus become encrusted in a Miocene matrix.



Tertiary Hache.
From Miocene Strata of Tagus Valley.
(Half the actual size.)
Quartrefages "Hommes Fossiles et Hommes Sauvages."

The verdict here, therefore, must be "Probable, but not proven." The same will apply to the alleged discovery of a human skull in California, buried under six distinct layers of hardened volcanic ashes, and certainly of Pliocene date, if not earlier. Whitney, the Director of the Geological Survey of the United States, and other American geologists, believe this skull to be Pliocene, but doubts have been thrown on its authenticity, and European geologists do not generally accept it.

A human bone is described by Lyell, which was found near Vicksburg in a side valley of the Mississippi, associated with bones of the extinct Mastodon and Megalonyx. But, although undoubtedly of great antiquity, there is no proof that it does not belong to the Quaternary period, especially as the mastodon seems to have lived until comparatively recent times in America, its remains being often found in recent bogs and peat mosses.

The same remark will apply to the skull which was found in digging a well at New Orleans, under six distinct layers of cypress forests such as are now growing on the surface, showing as many periods of successive subsidences, subsequent elevations, and stationary periods long enough to allow of a forest growth of many generations of large trees. Here again the antiquity must be very great, but we have no reason to carry it back into Tertiary periods, or beyond the recent period when the Mississippi began to flow in its present course and form its present delta.

Human remains have also been discovered in caves in Brazil associated with bones of extinct animals, but we have no clear infor-

mation as to the time when these animals became extinct, or as to the exact order of superposition in which the human skulls and implements were found, and the occurrence of a polished stone celt in the same cave throws still more doubt on their extreme antiquity.

The existence of Tertiary man must for the present be considered as resting on three instances:

1. The undoubted flint implements and cut bones (including those of the *Elephas meridionalis*, a Pliocene and Miocene species) of St. Prest.
2. The cut bones of the Balænotus from the Pliocene strata of Monte Aperto in Italy, the cuts on which appear to have been undoubtedly made by the hand of man armed with a sharp cutting stone implement.
3. The flints from the Miocene strata of Thenay, some of which show unmistakable signs of having been split by fire and chipped into shape by design.

On the other hand the evidence is entirely negative, that a large number of fossil animal remains have been found in various parts of the world, specially in the Pliocene of the Cromer forest bed, and the Miocene of the Sewalik hills, Pikermi and Nebraska, without finding any trace of man. This is true, and is sufficient to make us require great caution in admitting as fully established a fact of so much importance, which would carry back the antiquity of man from one or two hundred thousand years to at least a million. But the example of Quaternary man shows the danger of trusting too exclusively to negative evidence. Thirty years ago the negative evidence against his existence was considered conclusive. Now his remains have been found over the whole world and in thousands of instances.

It must be remembered, also, that remains of Tertiary man are not likely to be abundant. If man was then living, it was probably in fewer numbers and in more limited areas. The pressure of population had not yet driven wandering hordes to follow sea-coasts and cross rivers and mountains in pursuit of food. Probably at this early period man lived more on fruits, and therefore required fewer implements, and his intelligence was less, so that he had less power of fashioning them. For the purposes for which his Palæolithic descendents chipped stones into shape, he may have used natural stones which would often answer the purpose, but which, when thrown away, would leave nothing by which they could be recognized.

If the forests now inhabited by the gorilla and chimpanzee were submerged and again elevated, no trace would be found of the existence of animals which had built rude nests, used broken branches of trees as clubs, and cracked cocoa-nuts with hammer stones.

But above all, the surface of these older strata has been so much denuded, that the situations in which alone we might expect to find remains of man have almost entirely disappeared. Ninety-nine hundredths of our Quaternary implements come from river drifts or caves. Where are the Pliocene or Miocene rivers or caves? They have disappeared amidst the revolutions of the earth's surface and the constant denudation which wastes continents away. The negative evidence would be strong if we could point to caves filled with bone-breccias of a Pliocene or Miocene fauna, in which no trace was found of human remains. But it is weak as against even a single well-ascertained instance, if it merely amounts to such remains not being

frequently found where we could hardly expect to find them. And it is weak against the strong presumption that when Quaternary man is found in such numbers and under such conditions, spread over wide areas in inhospitable climates, he must have had his first origin in earlier times. It is, therefore, in the highest degree probable that this origin must have been in Tertiary times, when we know as a certain fact that large anthropoid apes were already in existence.

If this were so, what would it teach us as to the date of man's appearance?

Reckoning by the thickness of the different stratified deposits which make up the earth's crust, and assuming the average rate of their deposition, or what is the same thing, the average rate of waste of land surface to have been the same throughout, the whole Tertiary period carries us back barely one-twentieth part of the way towards the first beginnings of fossil-bearing strata. That is, if 100,000,000 years have elapsed since the earth became sufficiently solidified to support vegetable and animal life, the Tertiary period may have lasted for 5,000,000 years; or for 10,000,000 years, if the life-sustaining order of things has lasted, as Lyell supposes, for at least 200,000,000 years. Even if we take the shorter period, the time is ample for the enormous changes which have taken place since the commencement of the Eocene period. The average rate of denudation over the globe has been taken at about one foot in 3,000 years, from actual calculations of the average amount of solid matter carried down by the Mississippi and other great rivers. Now at this rate it would take only 2,000,000 years to wear the whole of Europe down to the sea-level, and, in the absence of any compensating movements of elevation, the whole of North America would be washed away and deposited in strata at the bottom of the Atlantic and Pacific Oceans in less than 3,000,000 years.

If, therefore, the origin of man could be traced down to the middle Miocene, or even to the date of the great anthropoid Dryopithecus of Southern France, we should have to assume a period for his existence of probably between one and two millions of years, a mere fraction of the time since the earth became the abode of life and existing causes operated to bring about geological formations.

As regards the habits and manners of Quaternary man we know very little that is positive, and can only gather some vague indications from the relics of caves and river drifts. These, however, are sufficient to establish with certainty that the law of his existence has been one of continued progress. The older the remains, the ruder are the implements and the fewer the traces of anything approaching to civilization. In the Neolithic period man is comparatively civilized. He has domestic animals and cultivated plants; he has clothing and ornaments, well-fashioned tools and pottery, and permanent dwellings. He lives in societies, builds villages, buries his dead, and shows his faith in a future life by placing with them food and weapons. As we ascend the stream of time these indications of an incipient civilization disappear. The first vestige of the domestic animals is found in the dog which gnawed the bones of the Danish kitchen-middens, and of the earliest Swiss lake-dwellings. When fairly in Palæolithic times even the dog disappears, and man has to trust to his own unaided efforts in hunting wild animals for food.

Weapons and implements become more and more rude until, in the oldest deposits, we find nothing but roughly-chipped hatchets,

arrow-heads, flakes, and scrapers. Implements of bone, such as barbed harpoons, borers, and needles, which are abundant in the midde Palæolithic or reindeer period, become ruder and disappear. Pottery, which is extremely abundant in the Neolithic period, either disappears altogether or becomes so scarce that it is a moot question whether a few of the rudest fragments found in caves are really Palæolithic. If so, they clearly date from the later Palæolithic, and pottery was unknown in the earlier Palæolithic times.

Judging from the portraits engraved on bone during the reindeer period, Palæolithic man pursued the chase in a state of nature, though from the presence of bone needles it is probable that the skins of animals may have been occasionally sewed together by split sinews to provide clothing. There can be no doubt that his habitual dwelling was in caves or rock-shelters. Here was his home, here he took his meals and allowed the remains of his food to accumulate. His staple diet consisted of the contemporary wild animals, the mammoth, the rhinoceros, the cave bear, the horse, the aurochs, and the reindeer. Even the great cave lion was occasionally killed and eaten, and the fox and other smaller animals were not despised; while among tribes skilled in the use of the bow and arrow, birds were a common article of food, and fish were harpooned by those who lived near rivers. Wild fruit and roots were also doubtless consumed, and from the formation of his teeth and intestines it is probable that if we could trace the diet of the earliest races of men we should find them to have been frugivorous, like their congeners the anthropoid apes.

The abundance of wild animals and the long period for which hunting savages inhabited the same spots may be inferred from the fact that at one station alone, that of Solutré in Burgundy, it is computed that the remains of no less than 40,000 horses have been found. All the long bones of the larger animals have been split to extract the marrow, which seems, as with the modern Eskimos and other savages, to have been a great delicacy, and also used for softening skins for the purpose of clothing.

Among the split bones a sufficient number of human bones have been found to make it certain that Palæolithic man was, occasionally at least, a cannibal; and in several caves, notably that of Chaleux, in Belgium, these bones, including those of women and children, have been found, charred by fire, and in such numbers as to indicate that they had been the scene of cannibal feasts. It is a remarkable fact that cannibalism seems to have become more frequent as man advanced in civilization, and that while its traces are frequent in Neolithic times, they become very scarce or altogether disappear in the age of the mammoth and the reindeer.

As regards religious ideas they can only be inferred from the relics buried with the dead, and these are scarce and uncertain for the earlier periods. The caves in which Palæolithic man lived on the flesh of the Quaternary animals, have been so often used as burying-places in long-subsequent ages, that it is extremely difficult to ascertain whether the skeletons found in them are those of the original inhabitants. Thus the famous cave of Aurignac, in which Lartet thought he had discovered the tomb of men at whose funeral feasts mammoths and rhinoceroses were consumed, is now generally considered to be a Neolithic burying-place superimposed on an abandoned Palæolithic habitation.

There are not more than five or six well authenticated instances

in which entire Palæolithic skeletons have been found under circumstances in which there is a fair presumption that they may have been interred after death, and these afford no clear proof of articles intended for use in a future life having been deposited with them. All we can say, therefore, is that from the commencement of the Neolithic period downwards, there is abundant proof that man had ideas of a future state of existence very similar to those of most of the savage tribes of the present day; such proof is wanting for the immensely longer Palæolithic period, and we are left to conjecture. The only arts which can with certainty be assigned to our earliest known ancestors are those of fire and of fashioning rude implements from stone by chipping. Everything beyond this is the product of gradual evolution.

CHAPTER VI.

MAN'S PLACE IN NATURE.

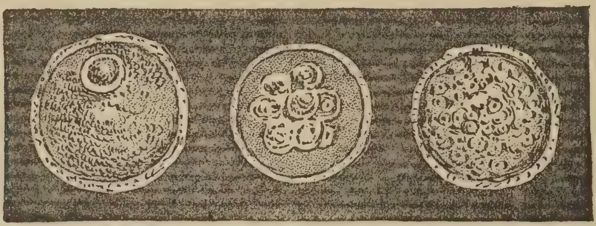
ALTHOUGH the establishment of the great antiquity of the human race has attracted more immediate attention, being a fact at once intelligible to the general public, the researches of anatomists and physiologists, aided by the microscope, have brought to light results quite as remarkable as regards the individual man and his place in Nature. Until recently it was taken for granted that man was a special miraculous creation, altogether superior to and distinct from the rest of the animal world. This assumption, gratifying alike to our vanity and our laziness in the laborious search for truth, has been to a great extent disproved and replaced by the Law of Evolution.

The most striking proof of this is found when we trace scientifically the growth of each individual man from his first origin to his final development. Man, like all other animals, is born of an egg. The primitive egg, or ovum, which was the first germ of our existence, is a small cell about the one-hundredth of an inch in diameter, consisting of a mass of semi-fluid protoplasm enclosed in a membrane, and containing a small speck or nucleus of more condensed protoplasm. This nucleated cell is itself the first form into which a mass of simple jelly-like protoplasm is differentiated in the course of its evolution from its original uniform composition. The nucleated cell is the starting-point of all higher life, and by splitting up and multiplying repetitions of itself in geometrical progression, provides the cell material out of which all the complicated structures of living things are built up. In sexual generation, which prevails in all the higher forms of life, this process requires, in order to start it, the co-operation of two such cells or germs of life, one male, the other female.

HUMAN EGG.
Magnified 100 times.

The first remarkable fact is that the human egg is, at its commencement, undistinguishable from that of any other mammal, and

remains so for a long period of its growth, going through its earlier stages of development in precisely the same way. At first the egg behaves exactly as any other single-celled organism, as for instance that of the amœba, which is considered the simplest form of organized life. It contracts in the middle and divides into two cells, each with its nucleus and each an exact counterpart of the original cell. These two subdivide into four, the four into eight, and so on, until at last a cluster of cells is formed which is called a *morula* from its resemblance to the fruit of the mulberry-tree. Development goes on, and the globular lump of cells changes into a globular bladder whose outside skin is built up of flattened cells. Then condensation takes place, from the more rapid growth of cells at particular points, and the foundation is laid of the actual body of the germ or embyro, the other cells of the germ-bladder serving only for its nutrition. Up to this point the germs not only of all mammals including man, but



MAMMALIAN EGG.
First Stage. Second Stage. Third Stage.

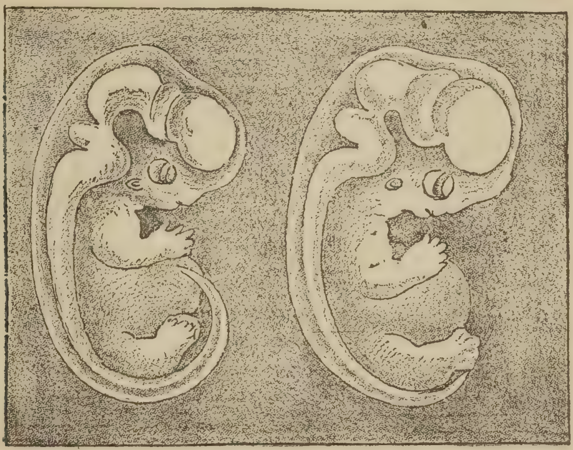
of all vertebrate animals, birds, reptiles, and fishes, are scarcely distinguishable.

In the next stage the outer surface of the embyro develops three distinct layers, the outer one of which, or epidermis, becomes the outer skin; the inner one, or epithelium, the mucous membrane or lining of all the intestinal organs; and the intermediate layer the raw material of muscles, bones, and blood-vessels. The embyro is now contracted in the middle and assumes the form of a violin-shaped disc, and a slight longitudinal furrow appears, dividing it into two equal right and left parts, which is gradually converted into a tube containing the spinal marrow, to protect which a chain of bones or vertebræ is developed, forming the back-bone.

And now comes what is the most marvellous part of the process, viz., the development of the brain, eye, ear, and other organs of sense, from these simple elements. The brain begins as a swelling of the foremost end of the cylindrical marrow-tube. This divides itself into five bladders, lying one behind the other, from which the whole complicated structure of the brain and skull is subsequently developed.

The eye, ear, and other sense-organs, begin in the same way. A slight depression in the outer skin extends until the edges close and form a hollow space in which the eye is formed. At first it is a mere black pigment mark on the interior surface of the inclosed space, which develops into the retina, with a wonderful apparatus of optic nerves for conveying impressions photographed on it to the brain. The enclosed space itself is filled with a fluid, or vitreous humor, from

which a lens is condensed for collecting the rays of light and concentrating them on the retina, and by degrees all the beautiful and complicated organs are evolved for perfecting the work of the eye and protecting it from injury. But this fact must be kept clearly in view: the process is identically the same as that by which the eyes of other animals are formed, and its various stages represent those by which the organs of vision have gradually risen to the development of a complete eye, in advancing from the lowest to the higher forms of life. Thus in the lowest, or Protista, the eye remains a simple pigment spot, which probably perceives light by being more sensitive to variations of temperature than the surrounding white cells. The next higher family develop a lens, and so on in ascending order, different families developing different contrivances for attaining the same object, but all starting from the same origin, development of the cells of the epidermis, and leading up to the same result, organs of vision adapted for the ordinary conditions of life of the creature which uses them. I say the *ordinary* conditions, for there are curious instances of the eye persisting, dwindling from disuse, and finally disappearing, in animals which live underground like the mole, or in subterranean waters like some fish in the Mammoth Cave of Kentucky and underground lakes of Carinthia, where the stimulus of light is no longer felt for many generations.



DOG (six weeks). MAN (eight weeks).
From Haeckel's "Schöpfungsgeschichte."

The history of the ear and other organs of sense is the same as that of the eye. They are all developments of the cell system of the outer skin, and all pass through stages of development identical with those at which it has been arrested in the progression from lower to higher forms of life. The same principles apply to the development of the inner organs, such as the heart, lungs, liver, etc., a striking illustration of which is found in the fact that the gill arches, or bones which support the gills by which fishes breathe, exist originally in man and all other vertebrate animals above the ranks of fish, but, in the develop-

ment of the embryo, they are superseded by the air-breathing apparatus of lungs, and converted to other purposes in the formation of the jaws and organ of hearing. In fact, we may say that every human being passes through the stage of fish and reptile before arriving at that of mammal, and finally of man.

If we take him up at the more advanced stage, where the embryo has already passed the reptilian form, we find that for a considerable time the line of development remains the same as that of other mammalia. The rudimentary limbs are exactly similar, the five fingers and toes develop in the same way, and the resemblance after the first four weeks' growth between the embryo of a man and a dog is such that it is scarcely possible to distinguish them. Even at the age of eight weeks the embryo man is an animal with a tail, hardly to be distinguished from an embryo puppy.

As evolution proceeds the embryo emerges from the general mammalian type into the special order of *Primates* to which man belongs. This order, beginning with the lemur, rises through the monkey, the baboon, and tailed ape, up to the anthropoid apes, the chimpanzee, gorilla, and orang, which approach nearest to the human type. The succession is gradual from the lower to the higher forms up to the anthropoid apes, but a considerable gap occurs between these and man. It is true that in his physical structure man resembles these apes closely, every bone and muscle of the one having its counterpart in those of the other. But even at its birth the human infant is already specialized by considerable differences. The brain is larger, its convolutions more complex, the spine has a double curvature, adapting it for an erect posture, and the legs, with a corresponding object, are longer and stronger, while the arms are shorter and less adapted for climbing. The thumb also is longer, making the hand a better instrument for all purposes, except that of clasping the branches of trees, for which the long, slender fingers of the ape are more available. The great toe also is less flexible and the foot more adapted for giving the body a firm support and less for being used as a hand.

As growth proceeds after birth these differences become more and more accentuated. The infant chimpanzee is not so very unlike the infant negro, but after a certain age the sutures of the skull close in the former, making the skull a solid box, which prevents further expansion of the brain, and the growth of the bone is directed towards the lower part of the face, giving the animal a projecting muzzle, massive jaws, and a generally bestial appearance, while at the same time its intelligence is arrested and its ferocious instincts become more prominent. Still these higher apes remain creatures of very considerable intelligence and warm affections, as may be seen in the behavior of those which have been caught young and brought up under the influence of kind treatment. There is a chimpanzee now in the Zoölogical Gardens at Regent's Park, which can do all but speak, which understands almost every word the keeper says to it, and when told to sing will purse out its lips and make an attempt to utter connected notes. In the native state they form societies, obey a chief, and often show great sagacity in their manner of foraging for food and escaping from danger.

Even in lower grades of life than the anthropoid apes we can see plainly many of the germs of human faculties in an undeveloped state.

Those who are fond of dogs, and have lived much with them and understood their ways, must have been struck by the many human-like qualities they possess, and especially by the very great resemblance between young dogs and young children. They both like and dislike very much the same people and the same mode of treatment. They like those who take notice of them, caress them, talk to them, and, above all, those whom they can approach with perfect confidence of receiving uniform kind treatment. They dislike those who have no sympathy with them, or whose treatment of them is either cold or capricious. Their great delight is to play with one another, and often to tease and make a pretence of quarreling and fighting. They both have an instinct for mischief, and are constantly trying it on how far they can go without getting into serious difficulties.

Later in life, and in more serious matters, the dog has certainly the germs of intelligence, and does a number of things which require a certain exercise of reasoning power. He has a good memory, and imagination enough to be excited at the prospect of a walk where there is a chance of finding a rat or a rabbit, and to dream of chasing imaginary rabbits when he is lying curled up on the hearthrug. Every dog has an individual character of his own as clearly defined as that of an individual man, nor can the rudiments of consciousness be denied to the hound who, in a kennel of twenty others, knows perfectly well that he is Rover, and not Rattler or Ranger, and waits till his name is called to come forward for a biscuit. When he has got it, his sense of property makes him appropriate it as his own, and respect the biscuits appropriated to other dogs, at any rate to the extent of knowing perfectly well that he is doing wrong if he takes them by force or steals them.

In the moral qualities the dog approaches even more closely to man. His fidelity, affection, and devotion even to death, are proverbial. He feels shame and remorse when he has departed from the canine sense of right and wrong or from the canine standard of honor, and is happy when he feels that he has done his duty. What is this but the working of an elementary conscience? Even in the higher sphere of religious feeling, the dog feels unbounded love and reverence for the master who is the highest being conceivable to him, or in other words, his God; and he shudders as that master does in the presence of anything weird and supernatural. Every good ghost story begins by describing how the dogs howled and shrank to their master's feet when the first shadow of supernatural presence was cast on the haunted castle.

Capacity for progressive improvement can hardly be denied to a race which has developed such qualities from ancestors who, like the wild and half-wild dogs of Asia and America, had not even learned to bark, and were as unlike the civilized and affectionate collie, as Palæolithic man to his modern successor. In fact, the progress of the dog seems only to be limited by the want of organs of speech, and of an instrument like the hand by which to place himself in closer relation with the outer world.

The same remarks apply to the elephant, whose great sagacity seems clearly attributable to the possession of such an instrument in the trunk, inferior no doubt to the hand, but still very superior to the paw of the dog or to the hoof-enclosed fore-foot of the horse. In all animals the greater or less perfection of the instruments by which they

act upon and are acted upon by the outer world, seems to be the principal factor in determining the quality of the brain as an organ of intelligence.

In the insect world we find still more wonderful exemplifications of the resemblance between animal and human intelligence. Ants live in organized societies, build cities, store up food for winter, keep aphides as milk-cows, carry on slave-hunting raids, and push the division of labor to such an extent that some tribes are all workers, others all warriors and slave-owners. These actions are not all merely mechanical and instinctive, for ants can to a considerable extent adapt themselves to circumstances, and alter their habits and mode of life when it becomes necessary in the "struggle for existence." The same is true of bees, beetles, and other insects, but it is useless to dwell on these, for the organization of the insect world is so different from that of the mammalian, to which man belongs, that no safe analogy can be drawn from one to the other. It is from the higher mammalian types that we can fairly draw the inference that, if like effects are produced by like causes, the more perfect intelligence, consciousness, and morality of man, must be the same in kind though higher in degree than the less perfect manifestations of the same qualities in animals of similar though less perfect physical organization.

There is one respect in which the human infant differs greatly from the young of other animals, viz., in the long period for which it remains in a condition of utter helplessness. In many of the lower forms of life the young creature emerges into the world with many of its necessary faculties complete, and has to learn comparatively little from education. The chicken runs about and picks up food on the day it escapes from the egg, and the young flycatcher will peck at flies with fragments of the shell still adhering to it. As we rise in the scale of creation, these instinctive aptitudes become fewer, and more time is required before the young animal can shift for itself; and at length, in the human infant, we arrive at a stage where for the first year or two it can do little to preserve its existence except to breathe and suck.

The reason of this is doubtless to be found in the higher development to which it is destined to attain. The faculties of every animal depend on two causes—first, heredity, or those which have been evolved from the type, and become fixed by succession through a long series of ancestors; secondly, adaptation, or those which are acquired by education, including in the term everything that is requisite to place the animal in harmony with its surrounding environment. The first are what are called instincts, which exist from the birth, and are preserved unconsciously and without an effort. The last involve an effort, and reference from the outer stations of the senses along the telegraph wires called nerves, to the central office of the brain, where the message is recorded and the reply considered and transmitted along another set of nerves to the muscles, where it translates itself into action. In either case the fundamental fact seems to resolve itself into a tendency of molecular motion to follow beaten rather than unknown paths. What the brain has once thought or perceived, it will think or perceive more readily a second time, and in like manner, a message which has once been transmitted and read off along a nerve, from muscle to brain or from brain to muscle, will be transmitted and read off more readily by practice, until at length it ceases to require

conscious effort and becomes instinctive. We may see an illustration of this in the facility with which a piano player, who began by learning the notes with difficulty, acquires such aptitude that the execution of rapid passages becomes mechanical, and can be carried on without a mistake, even when the performer is thinking of something else or talking to a bystander.

The outer world with which every animal has to deal from its birth upwards, may be compared to a dense forest or jungle through which it has to find its way. A certain number of paths have been cut by its ancestors, and it finds them ready made by heredity; others it constructs for itself by repeated efforts until they become as broad and easy as those which it inherited; and finally, if the forest is thick and its area extensive it can only be explored by leaving the beaten paths of inherited or acquired instinct, and groping the way painfully by conscious effort and attention.

We can now see why the lower the animal, or in other words the less extensive the forest, the whole vital energy may be concentrated on the few beaten paths opened by heredity, and a few necessary actions may be performed from the first, instinctively and with great perfection, while in higher organisms the vital energy is employed in developing a great mass of future possibilities rather than a small number of inferior present realities. The baby cannot run about the room and feed itself like the chicken, because the baby has to grow into a man or woman, while the chicken has only to grow into a fowl which can do very little more in its adult than in its infant state.

In fact, when we come to analyze the sum of faculties of the adult man, we find that they are derived to a surprisingly small extent from heredity as compared with education. In saying this, however, it must be understood that the term "heredity" is limited to that direct heredity which transmits characters by instinctive necessity, and not to the far larger sphere of indirect heredity by which faculties, arts, modes of thought, and rules of conduct, are accumulated in civilized societies, and become the principal instrument of education in its larger sense. If it were possible to suppose a human infant born of civilized parents, left entirely to itself, what would it grow into? Perhaps it would learn to walk, though this is not quite certain, as the few wild children who have been discovered in forests, went very much on all fours, and if we can believe the accounts of wolf children in India, those educated among wolves adopt their gait and habits; certainly it would not learn to speak, in the sense of using any articulate language; its arts would not extend beyond recognizing a few articles of food, and perhaps using stones to crack nuts, and constructing some rude shelter from branches of trees. It would know nothing of fire, and on the whole would not be so far advanced as its oldest Palæolithic ancestor.

As regards a moral sense, and all that we are accustomed to think the highest attributes of humanity, it is clear that his mind would be a blank. Even at a much more advanced stage, such ideas evidently come from education, and are not the results either of inherited instinct or of supernatural gift. An English child kidnapped at an early age by Apache Indians or head-hunting Dyaks, would, to a certainty, consider murder one of the fine arts, and the slaughter of an inoffensive stranger, especially if accomplished with a treachery that made the exploit one of little risk, an achievement of the highest man-

hood. If brought up among Mahometans he would consider polygamy, if among the Todas polyandry, as the natural and proper relation of the sexes. All that can be said is, that if recaptured and brought back to civilized society, he would perhaps be assisted by heredity in adopting its ideas more readily than would be the case if he had been born a savage.

It is clear, therefore, that the history of the individual man tells the same story of evolution from low beginnings as is told by that of the human race as traced from Palæolithic, through Neolithic, into modern times. His law is progress, worked out by conscious effort called forth by the environment of outward circumstances, and accelerated from time to time by the successful efforts of a few superior men, whose greater sum of energy or happier organization for development, enables them to pioneer new paths through the vast unexplored forests of science, art, and morality.

The difficulty of accounting for the development of intellect and morality by evolution is not so great as that presented by the difference in physical structure between man and the highest animal. Given a being with man's brain and man's hand and erect stature, it is easy to see how intelligence must have been gradually evolved, and rules of conduct best adapted for his own good and that of the society in which he lived must have been formed and fixed by successive generations, according to the Darwinian laws of the "struggle for life" and the "survival of the fittest."

But it is not so easy to see how this difference of physical structure arose, and how a being came into existence which had such a brain and hand, and such undeveloped capabilities for an almost unlimited progress. The difficulty is this: the difference in structure between the lowest existing race of man and the highest existing ape is too great to admit of the possibility of one being the direct descendant of the other. The negro in some respects makes a slight approximation towards the Simian type. His skull is narrower, his brain less capacious, his muzzle more projecting, his arm longer than those of the average European man. Still he is essentially a man, and separated by a wide gulf from the chimpanzee or gorilla. Even the idiot or *crétin*, whose brain is no larger and intelligence no greater than that of the chimpanzee, is an arrested man and not an ape.

If, therefore, the Darwinian theory holds good in the case of man and ape, we must go back to some common ancestor from whom both may have originated by pursuing different lines of development. But to establish this as a *fact* and not a *theory* we require to find that ancestral form, or, at any rate, some intermediate forms tending towards it. We require to find fossil remains proving for the genus man what the Hipparion and Anchitherium have proved for the genus horse, that is, gradual progressive specialization from a simple ancestral type to more complex existing forms. In other words, we require to discover the "missing link." Now it must be admitted that hitherto, not only have no such missing links been discovered, but the oldest known human skulls and skeletons, which date from the Glacial period, and are probably at least 100,000 years old, show no very decided approximation towards any such pre-human type. On the contrary, one of the oldest types, that of the man of the sepulchral cave of Cro-Magnon, is that of a fine race, tall in stature, large in brain, and on the whole superior to many of the existing races of mankind. The reply of

course is that the time is insufficient, and if man and the ape had a common ancestor, that as a highly developed anthropoid ape certainly, and man probably, already existed in the Miocene period, such ancestor must be sought still further back, at a distance compared with which the whole Quaternary period sinks into insignificance. It is said also that the discovery of man's antiquity is of quite recent date, and that thirty years ago the same negative evidence was quoted as conclusive against his existence in times and places which now afford his remains by tens of thousands. All this is true, and it may well make us hesitate before we admit that man, whose structure is so analogous to that of the animal creation, whose embryonic growth is so strictly accordant with that of other mammals, and whose higher faculties of intelligence and morality are so clearly not miraculous instincts but the products of evolution and education, is alone an exception to the general law of the universe, and is the creature of a special creation.

This is the more difficult to believe, as the ape family which man so closely resembles in physical structure, contains numerous branches which graduate into one another, but the extremes of which differ more widely than man does from the highest of the ape series. If a special creation is required for man, must there not have been special creations for the chimpanzee, the gorilla, the orang, and for at least 100 different species of apes and monkeys which are all built on the same lines?

What are the facts really known to us as to man, his nature, and his origin?

Man is one of a species of which there are in round numbers some 1,200 millions of individuals living at the present time on the earth. Taking thirty years as the average duration of each generation there are thus over 3,000 millions who are born and die per century, and this has gone on more or less during the period embraced by history which extends for a great part of the Old World over thirty centuries, in the case of Assyria and China over forty or fifty, and in Egypt over seventy centuries. At the commencement of these historical periods population was dense, probably in Egypt and Western Asia denser than at present, and civilization far advanced. The Pyramids, which are at the same time the oldest and the largest buildings in the world, prove this conclusively, both from the mechanical skill and astronomical science shown in their construction, and from the great accumulation of capital and highly artificial arrangements of society which could alone have rendered such works possible. The great mass of the population in these olden times lived in what is known as the Old World, and was accumulated mainly in the great valley systems of the Nile, and of the various rivers and irrigated plains of the southern half of the continent of Asia. Northern Asia and Europe were thinly inhabited by ruder tribes. Of America and the interior of Africa we know little until a much later date, but the populatian was in all probability sparse and savage, while in Australia, if it existed at all, it was still scantier and more savage; while in New Zealand and most of the Pacific Islands it has only been introduced by migration within comparatively recent times.

The next leading fact we have to observe is that the human race is not everywhere the same, but is divided into several well-marked varieties. The most obvious distinction is that of color. In the Old

World there are three distinct and clearly characterized groups—the white, the yellow, and the black. These are found mainly in three separate zoölogical provinces: the white in the temperate and north-temperate zones of Europe and Western Asia, the yellow in those of Eastern Asia, and the black in the tropical zone, principally of Central Africa. Where they are pure and unmixed, these race-types differ from one another not in color only but in many other important and permanent characters. The average size of the brain, the complexity of its convolutions, the shape of the skull, the bones of the face and jaws, the comparative length of the limbs, the structure of the hair and skin, the characteristic odor, the susceptibilities to various diseases, are all essentially different, so that no observant naturalist, or even observant child or dog, could ever mistake a Chinaman for a Negro, or a Negro for an Englishman.

Such a naturalist, seeing for the first time typical specimens of the three races, would pronounce them without hesitation to be distinct species, and would predict with much confidence that they would either not cross, or, if they did, would produce a hybrid progeny of inferior fertility.

But here he would be wrong, for, in fact, the most opposite races breed freely together, and produce a fertile progeny.

Moreover, when we extend our view beyond the clearly distinguished types of the white, yellow, and black, as seen in Caucasian, Mongoloid, and Negro races, we find these types breaking off into sub-types and shading off towards each other, while a large proportion of the human race consists of brown, red, olive, and copper-colored people, who may either be original varieties, or descended from crosses between the primitive races. Small isolated groups also crop up, differing from the main races, of whom it is hard to say from whom they are descended or how they got there; as for instance the Hottentots, in South Africa, the pigmy black Negritos of the Andamans and other South Asiatic islands, the Papuans and Australians, the hairy Ainos of Japan, and some of the aboriginal races of India.

To a certain extent climate seems to have had an influence in creating or developing the main typical differences. Thus the main line of black races lies along the hot tropical belt of the earth from Old to New Guinea. But the rule is not universal, there is no similar type in tropical America, where a singular uniformity of type and color prevails throughout the whole continent. Even in Africa we find the Negro type, while retaining its black color, shading off towards higher types and losing its more animal-like characteristics. Again, while color becomes generally lighter as we pass from tropical to south-temperate and from south to north-temperate regions, if we go still further north we find darker races, such as the Lapps and Esquimaux, and in one remarkable instance the color within the temperate zone itself actually becomes darker with increase of latitude, and the aboriginal savage of Tasmania, in a climate like that of Devonshire, was blacker than many negroes.

Even within great and well-defined races themselves there are clearly marked varieties. Thus the white race consists of the two distinct types of the fair-whites and dark-whites, the former prevailing in Northern Europe and the latter in Southern Europe, Western Asia, and North Africa; the contrast between a fair Swede with flaxen hair and blue eyes, and a swarthy Spaniard with black hair and

eyes, being almost as marked as between the latter and some of the higher black or brown races. Throughout a great part of Europe, including specially England, it is evident that the existing population is derived mainly from repeated crosses of these two races with one another and probably with earlier races.

In the existing state of things also it is evident that if the different races of mankind ever really did pass into one another under influences like those of climate, the time of their doing so is long past. A colony of English families transported to tropical Africa would to a certainty die out long before they had taken even the first step towards acquiring the black velvety skin, the woolly hair, the projecting muzzle, and the long narrow skull of the typical Negro, while a Negro colony transported to Scotland or Scandinavia would as certainly disappear from diseases of the chest and lungs, long before they began to vary towards the European type. The yellow race seems to be on the whole the best fitted to withstand climate and other external influences, and it certainly shows no signs anywhere of passing over either into the Caucasian or the Negro type.

On the whole, therefore, if the fact of fertile inter-crossing is to be taken as proving the unity of the human race and their probable descent from a common ancestor, and we are to assume that all the great varieties which we find existing are the result of modifications gradually introduced by climate and surrounding circumstances, it is evident that the point of divergence must be put at an immense distance.

This is the more certain, as when we look back for a period of more then 4,000 years, we find from the Egyptian monuments that some of the best-marked existing types have undergone no sensible change. The portraits of negroes and of Semitic dark-whites painted on the walls of temples and tombs of the 12th dynasty, about 2,000 B.C., might be taken as characteristic portraits of the negro and Jew of the present day, and the modern Egyptian fellah reproduces with little or no change the features of the Ancient Egyptians of the days of Rameses and Amenophis. It is evident, therefore, that where no great change has taken place from crossing of races, they will maintain their special characters unaltered for more than 100 generations. Indeed we might say for 200 generations, for the statues and wooden statuettes from the tombs of Sakkara, the ancient Memphis, which certainly date back for more than 5,000 years, show us the Egyptian type in its highest perfection, and with a more intellectual and I might say modern expression than is found 1,000 or 2,000 years later, when the type of the higher classes had evidently deteriorated somewhat from a slight infusion of African elements.

The same conclusion of the great distance at which any common point of divergence of the various races of mankind must be placed, is confirmed by a totally different line of inquiry, that into the origin of language.

Philologists have clearly proved that languages did not spring into existence ready made, like Minerva from the brain of Jupiter, but have followed the general law of Nature, and have had their periods of birth, growth, and evolution from simple into complex organism. Now there is a vast variety of languages, some say more than a thousand. A large proportion of these are, of course, only what may be called dialects of the same original language, as in the case of the

whole Indo-European family, including Sanscrit, Zend, Greek, Latin, Teutonic, Celtic, and Slavonic, with all their offshoots and derived branches, as well as many others. These can be all traced back to the common root of the primitive language of an Aryan white race, who radiated by successive migrations from some region in the elevated plateaux of Central Asia. Any one who wants to be convinced of this has only to refer to Max Müller's works and trace the history of one verb, viz., that used to denote individual existence.

Asmi in Sanscrit has become *eimi* in Greek, *sum* in Latin (whence *sono*, *suis*, and all the modern derivatives of Latin races), and "am" in English; while the Latin *est*, the Greek *esti*, and the German *ist*, are clearly akin to the original *asti*. It may help in understanding how language has been formed if we point out that "I am" originally meant "I breathe," and "he is" is the more general and abstract form of "he stands."

But there are a number of languages between which no such relationship can be traced, which are constructed on radically different principles, and have no resemblance with one another in their roots, or primitive sounds used to express objects and simple ideas, except in the few cases where it can be traced to importation from abroad, or to imitation of naturally suggested sounds, such as those which have led so many nations to express the idea of "mother" by a sound resembling the bleating of a lamb. Obviously, similarity of sound in such words as are used for the ideas of father, mother, cow, crow, thunder, crack, splash, and so on, suggests no common origin, and as most, or at any rate a great many roots, were probably derived originally in this manner, though long since diverted to express other ideas by associations which it is impossible to trace, the wonder rather is that we should find so many languages with so few roots in common. The best authorities tell us that a list of fifty to one hundred languages could be made of which no one has been satisfactorily shown to be related to any other.

The main distinction between languages, however, is to be found in their inner mechanism, or grammar, rather than in the mere difference of root-sounds. The result of years of mechanical training in barbarous Latin and Greek grammars in our English public schools has been to leave the average Englishman completely ignorant of the real meaning of the word "grammar," and almost incapable of comprehending that it can mean anything else than a string of arbitrary rules to be learned by heart for the vexation of small boys.

And yet grammar is really most interesting, as showing the modes by which the dawning human intellect has proceeded, at remote periods and among different races, in working out the great problem of articulate speech, by which man rises into the higher regions of thought and is mainly distinguished from the brute creation. Consider first what the problem is, and then some of the principal modes which have been invented to solve it.

Suppose some primitive race to have accumulated a certain stock of root-words, or simple sounds to signify definite objects and simple ideas, they must soon find that these alone are not sufficient to convey briefly and clearly to other minds the ideas which they wish to express. For instance, suppose a tribe had got root-words to express the ideas of "man," "bear," and "kill." What one of the tribe wants to convey from his own mind to that of his neighbor may be, "The

man has killed the bear," or "The bear has killed the man," or "The" (or "A) man has killed a bear," or "bears," or "will" or "may have" killed, and so on through a vast number of variations on the original three-note theme. Up to a certain point, a man might succeed in making himself understood by using his three root-sounds in a certain order, aided by the pantomime of accent and gesture; and the Chinese, though one of the oldest civilized peoples of the world, have scarcely got beyond this stage. But the process would be difficult and uncertain, and at length it would occur to some genius that such modifications as those of definite and indefinite, past and present, singular and plural, etc., were of general application, not to the particular three or four roots which he wished to connect, but to all roots. The next step would be to invent a set of sounds which, attached in some way to the root-sounds, should convey to the hearer the sense in which it was intended that he should take them.

This is the fundamental idea of grammar, but it has been worked out by different races in the most different manner. The Chinese and other allied races in the South-east of Asia, such as the Burmese and Siamese, have solved it in the simplest manner. Their languages are what is called monosyllabic—that is, each word consists of a single syllable, and is a root expressing the fundamental idea, without distinction of noun from verb, active from passive, or other modifications. They have to trust, therefore, to express their meaning, mainly to syntax, or the order in which words succeed one another, which, up to a certain point, is the simplest method, and is largely adopted in modern English. Thus, "Man kill bear," "Bear kill man," convey the meaning just as clearly as the classical languages do by cases, when they distinguish whether the man is the killer or the killed by saying *homo* or *hominem*. But the monosyllabic system limits the nations who use it to an inconveniently small number of words, and fails in expressing their more complex relations, so that we find the same word in Chinese or Siamese often expressing the most different ideas, and the meaning can only be conveyed by supplementing the root-words and syntax by accent and other conventional signs which are akin to the primitive devices of gesture language. Thus, in Siamese, the syllable *ha*, according to the note in which it is intoned, may mean a pestilence, the number five, or the verb "to seek."

This very primitive and almost infantine form of language is confined to one family, that of the Chinese and Indo-Chinese, who, it may be observed, are by no means simple or primitive in other respects, but stand and have stood for centuries at a comparatively high level of civilization. All other races, including the most savage, have adopted some form or other of grammar, *i.e.*, of modifying original root-sounds by additional generic sounds of definite determination; but the devices on which they have hit for this purpose are most various. Thus, the grammar of the Aryan family of languages has been formed by reasoning out such general categories of thought as articles, pronouns, and prepositions, coining sounds for them and prefixing these sounds to the root-sounds as separate determinating signs. More complex shades of meaning are conveyed principally by inflections, *i.e.*, by adding certain generic new sounds to the the original root-word, and incorporating them with it so as to form modifications which are a sort of secondary words. Thus the ideas of present, past, and future love, loving, and being loved, lovely, and so on, are formed by transforming the root

amo into such modifications as *amor*, *amavi*, *amabo*, *amans*, *amabilis*, etc. We can see this process in the course of formation in the change which converted the old English form "Cæsar his" into the modern genitive "Cæsar's."

Other families again obtain the same results by very different processes. The Semitic languages, for instance, including Hebrew, Arabic, Assyrian, and Phœnician, are what is called "triliteral," *i.e.* they consist of roots mostly of three consonants, and express different shades of grammatical meaning by altering the internal vowels. Thus from the root m-l-k are derived *melek*, a king; *malak*, he reigned, and so on.

The Turanian family, comprising Huns, Turks, Finns, Lapps, and other Mongolian races of Northern Asia, all speak agglutinative languages, *i.e.*, languages in which the root is put first and is followed by suffixes strung on to it, but not incorporated with it and remaining distinct. Thus in Turkish, the root *sev*, to love, is expanded into *sevishdirilmedeler*, meaning "incapable of being brought to love one another."

These are only given as specimens of some of the most marked of the vast varieties of language which have been examined and classified by philologists. They suggest a great many interesting reflections, but I confine myself to those which bear more immediately on the subject of man's origin and development. It is evident that they imply great antiquity for the existence, not of man only, but of separate races of men speaking separate languages.

Babylonian inscriptions, quite 4,000 years old, show that the characteristic features of the Aryan and Semitic languages were as clearly established then as they are now; and the hieroglyphics of Egyptian monuments, 1,000 years older, show the Coptic language essentially the same as modern Coptic, and although presenting some points of analogy with Semitic, too different to be classed with it. If these are descended from a common ancestor, clearly their origin must be extremely remote. And even with unlimited time it is difficult to conceive how such radical differences in the structure of languages could have arisen unless the different races had branched off before any clear form of articulate speech had become fixed. Could a race accustomed for generations to the free-flowing inflectional Aryan, have deserted it for the cramped forms of the Semitic, or *vice versâ*, could the Semite have adopted the modes of thought and expression of Sanscrit? And the same difficulty would apply in at least twenty or thirty cases of other families of language.

It must be recollected that language is not merely the conventional instrument of thought, but to a great extent its creator, and the mould in which it is cast. The mould may be broken, and races abandon old and adopt new languages by force of external circumstances, such as conquest or contact with and absorption by superior races, but there is no instance of its being so transformed from within as to pass into a totally different type. Nor can we very well see how root-words once attached to fundamental ideas, such for instance as the simpler numerals, should come to be forgotten and new and totally different words invented.

Of course, the explanation was easy in the olden days, when everything was referred to miracle. Languages were different because God had made them so, to baffle the attempt of united mankind to

build a tower high enough to reach to heaven. But the theory of special miraculous creation for each language cannot stand a moment's investigation.

As in the case of the animal world, special creations, if admitted at all, must be multiplied to an extent which becomes absurd. Is every petty tribe of savages who speak a language unintelligible to others to be supposed to have had it conferred upon it as a miraculous gift? Was the language of the extinct Brazilian tribe, of which Humboldt tells us that a very old parrot spoke the last surviving words, one of the languages used to scatter the builders of the Tower of Babel? Or, still more conclusively, where we know and can prove that one part of a language is the product of natural laws, can we assume that another part of the same language is the result of miracle? Did it require Divine inspiration to make the old Egyptians call a cat *miaou*, or to teach so many nations to express the idea of mother by imitating the bleating of a lamb? If not, why should half the words in a dictionary be miraculous and half natural?

And if Cæsar is correctly reported to have been more proud of discovering a new case than of conquering Gaul, ought we not to "render unto Cæsar the things that are Cæsar's," and assign grammar as well as words to human invention? In short, no reasonable man who studies the subject can doubt that language is just as much a machine of human invention for communicating thought, as the spinning jenny is for spinning cotton.

The general conclusion, then, to be drawn from the study of language points in the same direction as that of all other branches of science, viz., that their true history is that of evolution from simple origins by the operation of natural laws over long periods of time into forms of greater complexity and higher development. What language really does for us is to take up the thread where the oldest history fails us, and show that even at this date it is impossible to doubt that the human race must have been already in existence for a very long period, and in existence as at the present day in several sharply distinguished varieties, so that the common origin, if there be one, must be placed still further back. As history verified by the Egyptian monuments extends over a period of nearly 7,000 years, this is equivalent to saying that such a period can only be a very small part of the total time which has elapsed since man became an inhabitant of the earth.

The origin and development of religions have been much discussed, but too often with a desire to make theories square with wishes. The subject also does not admit of such precise determination as in treating of arts and languages, which have left traces of themselves in the form of primitive implements and primitive roots.

The history of religions really begins with written records, or at the earliest with the older myths which are embodied in these records. But these are all comparatively modern, and imply a considerable progress in civilization before they could have existed. If we wish to form some idea of what may have been the primitive elements from which religion was evolved, during the long Neolithic and still longer Palæolithic periods which preceded history, we must look at what are actually the religious ideas of contemporary savage and semi-barbarous races.

At the very lowest stage of savagery we find races like the Aus-

tralians, the Bushmen, the Mincopies, and the Fuegians, who cannot be said to have any religion at all, or at the most some vague ideas of ghosts and spirits. The Mincopies of the Andaman Islands, who are considered by Professor Owen as "perhaps the most primitive, or lowest in the scale of civilization, of the human race," are reported by Dr. Mowatt to have "no idea of a Supreme Being, no religion, nor any belief in a future state of existence." Sir J. Lubbock says of the Australians that "they have no religion, nor any idea of prayer; but most of them believe in evil spirits, and all have great dread of witchcraft."

As we rise above this level of the lowest savagery we find ideas of religion beginning to grow from two main tap-roots. The first is the idea of ghosts or spirits, which arises naturally from dreams and visions and develops itself into ancestor and hero-worship, and belief in a world of spirits, good and evil, influencing men's lives and fortunes, and in many forms of sickness taking possession of their bodies. This spirit-worship also necessarily leads to some dim perception of a future life.

The other tap-root is the inevitable disposition to account for the phenomena of nature, when men first began to reflect on them, by the agency of invisible beings like themselves; in other words, of anthropomorphic gods. This is a higher and later stage of religious belief than the former, for it implies a certain disposition to inquire into the causes of things and a certain amount of reasoning power to infer like causes from like results.

But the two often blend together, as in the religions of the Aryan race, in which we see deified heroes and ancestors crowding the courts of Olympus, with a multitude of anthropomorphic gods, who are often merely obvious personifications of natural phenomena or astronomical myths. Thus Varuna, Ouranos, or Uranus, are personifications of the vault of heaven; Phœbus, the shining one, of the sun; Aurora, of the dawn; while Hercules is half deified hero and half solar myth. Sometimes, however, of the two stems of religion one only has flourished, and the other has either never existed, or been overshadowed by the first and relegated to a lower sphere. Thus the great Chinese civilization, comprising such a large portion of the human race, has apparently developed its religion entirely from the idea of spirits and spirit-worship. The worship of ancestors is its main feature, and its sacred books are, in effect, treatises on ethics and political economy, with rules for rites and ceremonies to enforce decent and decorous behavior, rather than what we should call works of religion. There is no trace of a conception of anthropomorphic gods in the genuine national Chinese religion from Confucius downwards; and even the introduction of Buddhism has done little but add the deified hero, Buddha, to the list of divine ancestors and give more definite shape to various vague superstitions. In like manner the whole Buddhist world can hardly be said to recognize anything beyond their incarnate hero, except a Nirvana or metaphysical abstraction, rather than a personal deity.

With other races again, and specially the Hebrew, the idea of a tribal anthropomorphic God has gradually swallowed up that of other gods, developed into that of one Almighty Being, and dwarfed that of ghosts and spirits. The primitive Hebrews, indeed, carried this so far as to exclude all ideas of a future life from their religious system.

Their primitive God, however, was strictly anthropomorphic, and modelled on the idea of an Oriental sultan—sometimes good and beneficent, but sometimes cruel and capricious, and above all jealous of any disrespect and enraged by any disobedience. Morality seems at first to have had little or nothing to do with these conceptions, and there is not the remotest trace in the early history of any religion, of its having been born ready-made from the necessary intuition of one Almighty God of love, mercy, and justice, which is so confidently assumed by many metaphysicians and theologians. On the contrary, conscience had to be first evolved, and the process may be followed step by step by which, as manners became milder and ideas purer, the grosser attributes of Deity were gradually purged off, and the idea of a just and merciful God was evolved from barbaric elements.

These considerations, however, lead us far from the question of the first dawn of religion among primitive man. Judging from the earliest facts of history, and the analogy of modern savage races, where we might look for the first traces of religious ideas would be from the contents of tombs and from idols. When a tribe had attained to some definite idea of a future life it would almost certainly bury weapons and implements with its dead, as is the case with modern savages. When it had reached the stage of worshipping anthropomorphic deities, it would probably frame images of them, some of which would be found in their tombs and dwellings.

The latter test soon fails us. In the early Egyptian tombs, and in the remains of the prehistoric cities excavated by Dr. Schliemann, images of owl and ox-headed goddesses, and other symbolical figures or idols, are found in abundance. But when we ascend into Neolithic times, such idols are no longer found, or, if found, it is so rarely that archæologists still dispute as to their existence. Certain crescents found in the Swiss lake-dwellings were at one time thought to indicate a worship of the moon, but the better opinion seems to be that they were used as rests for the head during sleep, as we find similar objects now used in many parts of the world. Among the many thousand objects recovered from these Swiss lake-dwellings and other Neolithic abodes, there are only a very few which may possibly have been rude idols or amulets, and the only ones which may be said with some certainty to have been idols, are one or two discovered by Mons. de Braye in some artificial caves of the Neolithic period, excavated in the chalk of Champagne, which appear to be intended for female figures of life size with heads somewhat resembling that of the owl-headed Minerva.

When we pass to Palæolithic times the evidence of idols becomes more faint, and rests solely on the conjecture that some of the figures carved by the Reindeer-men of La Madeleine and other caves, may probably have been intended for amulets. As they were such skilful carvers, and so fond of drawing whatever impressed itself on their imagination, the presumption is strong that they had not advanced to the stage when the worship of gods symbolized by idols had come into existence, as otherwise more undoubted idols must have been found in the caves which were so long their habitations, and which have yielded such a number of remains of works of art.

The evidence for a belief in a future existence and in spirits is more conclusive. Throughout the whole Neolithic period we find objects buried with the dead which were evidently intended for use in

a future life. We find also in many Neolithic tombs a singular fact which points to the existence of a very long belief in evil spirits. Many of the skulls, especially of young people, have been trepanned, that is, a piece of the skull has been cut out, making a hole, apparently to let out the evil spirit which was supposed to be causing epilepsy or convulsions; and where the patient had recovered and the wound healed, when he died long afterwards, a piece of the skull, including this trepanned portion, was sometimes cut out and used apparently as an amulet. The objects deposited in graves show that the idea of a future life was, as with most savages of the present day, that of a continuation of the same life as he had led here, though perhaps in happier hunting-grounds. In some cases a great chief seems to have had wives and slaves slaughtered and buried with him, though the proofs of this are more clear and abundant in later prehistoric times than during the Neolithic period. Cannibalism, however, seems to have occasionally prevailed both in Palæolithic, Neolithic, and prehistoric times, as it did so extensively among modern savage races before they came under civilizing influences. This is clearly proved by the number of human bones, chiefly of women and young persons, which have been found charred by fire and split open for extraction of the marrow.

The evidence of belief in a future life becomes more rare and uncertain in Palæolithic times. Perhaps it may be because we have so few authentic discoveries of Palæolithic burying-places, and so many instances of caves, once inhabited by Palæolithic races, being used long afterwards as Neolithic sepulchres. After the famous cave of Aurignac it is difficult to trust any evidence of the discovery of a real Palæolithic sepulchre which has not been subsequently disturbed.

In the few cases also where Palæolithic skeletons have been found, as in that of the men of Neanderthal and Mentone, they have often been those of single individuals, and it may be doubted whether they were buried there, or merely died in the caves in which they lived, in which case any implements found with them do not necessarily imply that they were placed there for use in a future life. On the whole it seems doubtful whether any certain proofs of burials denoting knowledge of a future life can be found in Palæolithic times, and if there are, they are certainly few and far between, and confined to the later stages of that period.

All we can say is, that religion certainly did not descend ready-made among these aboriginal savages, but that, like language, it was slowly developed from beginnings as rude as those we now find among the lowest races of savages.

It may be well, however, to say here, once for all, what is applicable to many other passages in this book, that the question of the origin of any religion is entirely different from that of its truth or falsehood. To explain a thing is not to disprove it; on the contrary, a thing only really becomes true to us when we understand it. A stately oak, with wide-spreading branches, that give shade and shelter to the cattle of the fields, is not the less a fact because we know that it did not drop ready-made from heaven, but grew from an acorn. The intrinsic truth of a religion must be tested by the conformity which, in a given stage of its evolution, it bears to the facts of the universe as disclosed by science, and to the feelings and moral perceptions which have been equally developed by evolution in the contemporary world.

All I contend for is, that all religions have grown and been developed from humble origins, and that their history, impartially considered, does not contradict, but on the contrary greatly confirms the law of natural evolution.

Of the two faculties by which man is commonly distinguished from the brute creation, viz., that of being the speaking and the tool-making animal, the former attribute has been shown to be the product of evolution from origins long since lost in the far-off distance of remote ages.

The same remark is even more certainly true as regards the other attribute of tool-making, or, in its widest sense, adapting natural laws and natural objects to the arts of life by intelligent application. The primitive roots, so to speak, of this industrial language, which in the case of spoken language for the most part elude our search, are here furnished by the Palæolithic remains found so abundantly in river drifts and caves. There can be no doubt whatever that the modern wood-cutter's axe and carpenter's adze are the lineal descendants of the rudely-chipped *hâches*, or celts, which are dug out of the gravels of St. Acheul, or from below the stalagmite of Kent's Cavern. The regular progression can be traced from the mass of flint rudely chipped to a point, with a butt-end left rough to grasp in the hand, up to more symmetrical and carefully-chipped forms; to implements intended to be hafted or fastened to a handle; to implements ground and polished to a sharp edge and pierced for the handle; and finally to the finished specimens of the later Neolithic period, which exactly represent the adze and battle-axe, and are almost identical with those used quite recently by the Polynesians and other semi-civilized races who had no access to metals. From these the transition to metals is easily traced, the first bronze implements and weapons being facsimiles of those of polished stone which they superseded, and the gradual development of bronze, and from bronze to the cheaper and more generally useful metal, iron, being a matter of quite modern history.

In like manner, the development of the knife, sword, and all cutting instruments, from the primitive flint flake, can be traced step by step, and is beyond doubt; and equally so the development of all missils, from the primitive chipped flint, used as a javelin or arrow-head, up to the modern rifle. When we catch the first glimpes of the beginnings of human art or industry, the furniture or stock-in-trade of Palæolithic man appears to have been as follows:

He was acquainted with fire. This seems to be clearly established by the charred bones, charcoal, and other traces of fire which are found in the oldest Palæolithic caves, and even in the far distant Miocene period, if we can believe in the flints discovered by the Abbé Bourgeois in the strata of Thenay, some of which appear to have been split by the action of fire. This is a remarkable fact, for a knowledge of the means of kindling fire is by no means a very simple or obvious attainment. Apes and monkeys will sit before a fire and enjoy its warmth, but no monkey has yet developed intelligence enough even to put fresh sticks on to keep up the fire, much less to rekindle it when extinct. Primeval man must often have had experience of fire from natural causes, as from forests and prairies scorched by a tropical sun being set on fire by lightning, or from volcanic eruptions; but how he learned from these to kindle fire for himself is not so obvious. Savage races, as a rule, do so by converting mechanical energy into heat, by

the friction of a stick twirled round in a hole, or rubbed backwards and forwards in a groove in another piece of wood; and there are old observances among civilized nations which show that this was the mode practiced by their ancestors, as when the sacred fire in the Temple of Vesta was relighted in this manner by the old Romans if it had chanced to be extinguished. It is probable, therefore, that this was the original mode of obtaining fire, but if so, it must have required a good deal of intelligence and observation, for the discovery is by no means an obvious one, nor is it easy to see any natural process that might suggest it.

Neither ancient history nor the accounts of existing savage races throw much light on the question. The narratives of the discovery of fire contained in the oldest records are obviously mythical, like the fable of Prometheus, which is itself a version of the older Vedic myth of the god Agni (whence the Latin *ignis* or fire) having been taken from a casket and given to the first man, Manou, by Pramantha, which in the old Vedic language means taking forcibly by means of friction. Of the same character are the mythical legends of savage races of fire having been first brought by some wonderful bird or animal; and there is nowhere anything like an authentic tradition of the fact of its first introduction. There have been reports of savages who were unacquainted with fire, but they have never been well authenticated, and the nearest approach to such a state of things was probably furnished by the aborigines of Van Diemen's Land, of whom it is said that in all their wanderings they were particularly careful to bear in their hands the materials for kindling a fire, in the shape of a firebrand, which it was the duty of the women to carry, and to keep carefully refreshed from time to time as it became dull.

On the whole, traditions all point to fire having been first obtained from friction, and it is possible that the first idea may have been derived from the boughs of trees, or silicious stalks of bamboos, having been set on fire when rubbed together by the action of the wind.

It is easier to see the origin of the remaining equipment of primitive man, viz., chipped stones, for flints splintered by frost or fire often take naturally the forms of 'sharp-edged flakes and rude hatchets or hammers, and very little invention was required to improve these specimens, or endeavor to imitate them by artificial chippings. It is rather surprising that this art did not improve more rapidly, for it is evident that the old Palæolithic period must have lasted a long time before any decided progress began to show itself. And during this long period a singular uniformity appears to have prevailed throughout the Palæolithic world. The rude form of the celt or *hâche*, with a blunt butt and chipped roughly to a point, is found in the oldest river gravels and caves wherever they have been investigated, and the forms of the Somme and the Thames are repeated in the quartzite implements of the Madras laterite.

In the very oldest caves and river deposits the tool-equipment of man seems to have been very much limited to these rude celts, used probably for smashing skulls in war and the chase, and splitting bones to get at the marrow; sharp-edged flakes for cutting; rude javelin-heads; and stones chipped to a rounded edge, very like those used by the Esquimaux for scraping bones and skins. As we ascend in time we find arrow-heads of stone and bone, at first unbarbed and gradually

becoming barbed, showing that the bow had been discovered; harpoons of bone and fish-hooks; bone pins and needles; and a much greater variety and more carefully-chipped forms of flint tools and weapons; until we finally reach the upper reindeer stage of caves like that of La Madeleine, where artistic drawings and carvings are found, and the equipment generally is superior to that of many existing savage tribes, and not much inferior to that of the Esquimaux and other Arctic races.

We then pass into Neolithic times, when many of the chief elements of civilization are already in full force. Man has emerged in many localities from the hunter into the pastoral stage, the principal domestic animals are known, and in some of the later lake-dwellings he has advanced a stage further, and has become an agriculturist living in villages. From this to the Bronze and early historical periods, there is no great break, and the ruder tribes of barbarians described by Cæsar and Tacitus may well have been the lineal descendants of the Neolithic men whose polished axes and finely-shaped arrow-heads lie scattered over the surface of Europe and are found in innumerable burial-mounds and dolmens.

But in Palæolithic times, though we can see constant progress, mankind is still in a state of unmitigated barbarism. Agriculture was clearly unknown, for the hand-mills, pestles, and mortars, which are among the most enduring and abundant relics where grain was used for food, are never met with. Pottery was unknown in all the earlier periods, and it is questionable whether even the rudest forms of baked clay, moulded by hand, are found where there is no intermixture of a subsequent Neolithic habitation. The dog was clearly not a companion of man prior to the era of the Danish kitchen-middens, for the spongy parts of bones which are always gnawed by dogs when dogs are present, are invariably preserved in the *débris* of Palæolithic caves, and the few bones of dogs, wolves, and foxes found with human remains in these caves almost always show that the animals had formed part of the food of the inhabitants.

Other domestic animals were, in all probability, equally unknown, although it has been thought possible that some of the tribes of the reindeer period may have had herds of the half-tame deer, like the modern Laplanders. This conjecture, however, appears to rest solely on the large number of bones and horns found at certain stations, which may have arisen from their having been occupied for a very long period, and as the dog was unknown, it seems probable that no other animals had been domesticated.

As regards clothing, the first certain proofs of its use are afforded by the bone pins and needles, which were evidently employed for fastening the skins of animals together, and the scrapers were probably used for scraping these skins and fashioning the bone implements. It is probable, therefore, that the use of skins as a protection against the cold of the Glacial period, was known at a very early period.

Ornaments, also, are of very early date, as pierced shells, sometimes fossil, and pierced teeth of the bear and other animals are frequently found under circumstances which show that they must have been strung together as necklaces. The skeleton found in a cave at Mentone had a number of perforated shells of Nassa, and a few stag's teeth also perforated, dispersed about the skull, so as to show that they had formed some sort of head ornament. Lumps of red hematite, also, probably used for paint, have been found in some of the caves of the reindeer period

DEVELOPMENT OF THE ARROW.

FLINT ARROW IN VERTEBRA OF REINDEER.
Palæolithic. La Madeleine.

PALÆOLITHIC.
Mammoth Period. Le Moustier.

PALÆOLITHIC.
Reindeer Period.
First vestige of barb.

PALÆOLITHIC.
Reindeer Period.

PALÆOLITHIC.
Reindeer Period.

NEOLITHIC.
Denmark.

NEOLITHIC.
Ireland.

NEOLITHIC.
Denmark.

RECENT.
Esquimaux.

(From Lubbock's "Prehistoric Times.")

Captain Cook's description of the savages of Tierra del Fuego would have applied to them, that, "although content to be naked, they were very ambitious to be fine;" and probably like these poor Fuegians, they adorned themselves with streaks of red, black, and white, and wore bracelets and anklets of shell and bone.

If we wish to form some idea of the manners and customs of our Palæolithic ancestors, we must look for them among the existing savage races, whose mode of life, and equipment of tools and weapons, most nearly resemble those of the earliest cave-dwellers. The Australians, the Bushmen of South Africa, the Mincopies of the Andaman Islands, and the Fuegians are probably the lowest specimens of the human race known in modern times; but even these are in some respects further advanced in the arts than the first Palæolithic man. The Bushmen are skilled in the use of the bow, and have discovered the art of poisoning their arrows. The Australians, Mincopies, and Fuegians have canoes, harpoons, and fish-hooks. The latter approach more nearly to the conditions of life of the savages who accumulated the kitchen-middens on the coasts of Denmark at a much later period, and the Bushmen probably represent better those of the cave-men who lived principally on the produce of the chase of large animals, such as the mammoth, rhinoceros, cave bear, horse, and deer. The pigmy Bushman will attack the elephant, the rhinoceros, and even the lion, and often succeed in killing them by pitfalls or poisoned arrows.

The inferences, therefore, to be drawn, alike from the physical development of the individual man, and from the origin and growth of all the faculties which specially distinguish him from the brute creation —language, religion, arts, and science—all point to the conclusion that he is a product of laws of evolution, and not of special or miraculous creation.

Still, admitting this, we must admit on the other hand, that until more of the "missing links" are discovered, and the origin of man is placed on a basis of scientific certainty, there is an opening left for the belief that here, if nowhere else, there was some supernatural interference with the laws of Nature, and that the finger of the clock-maker did here alter the hands of the clock from the position which they would have occupied under the original law of its construction. But if this were so, it must equally in candor be admitted that the miracle did not consist in placing man and woman upon earth, at any recent period, or with faculties in any way developed, but could only have consisted in causing a germ or germs to come into existence, different from any that could have been formed by natural evolution, and containing within them the possibilities of conscious and civilized man, to be developed from the rudest origins by slow and painful progress over countless ages.

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